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PROCEEDINGS OF NATIONAL SYMPOSIUM ON FOOD PROCESSING WASTES (3rd), HELD AT NEW ORLEANS, LOUISIANA ON 28-30 MARCH 1972.

Pacific Northwest Water Laboratory
Corvallis, Oregon

November 1972

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Environmental Protection Technology Series

PB 214 418

PROCEEDINGS THIRD NATIONAL SYMPOSIUM ON FOOD PROCESSING WASTES

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16. Abstract

There were 23 papers presented on process modification, by-product recovery, process water reduction, and wastewater treatment for many different types of food processing.

Approximately 300 members of industry, consulting firms, universities, and state and federal agencies participated in the 3-day meeting in New Orleans, La., where such items as dry caustic peeling, vegetable blanching, reverse osmosis, ultrafiltration, biological treatment, tertiary treatment, wastewater characterization, ocean assimilation, and federal research and effluent guidelines were discussed.

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PROCEEDINGS THIRD NATIONAL SYMPOSIUM ON FOOD PROCESSING WASTES

March 28-30, 1972
New Orleans, Louisiana

National Waste Treatment Research Program
Pacific Northwest Water Laboratory
200 S.W. 35th Street
Corvallis, Oregon 97330

Program Element No. 1B2037

NATIONAL ENVIRONMENTAL RESEARCH CENTER
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FOREWORD

This Third National Symposium on Food Processing Wastes was held concurrently with the American Society of Mechanical Engineer's Process Industries Division meeting on Waste Water Reuse in Industry. Early in the planning stages it was learned that both ASME and EPA were planning meetings in New Orleans at approximately the same time with the same general theme, and so it was decided to hold a concurrent meeting in the interest of efficiency.

The National Symposium on food processing waste was again co-sponsored this year with the National Canners Association. Much of the success of the meeting and the interest and participation by industry is attributed to the efforts of NCA in publicizing and encouraging attendance at the meeting.

The technical papers presented at the sessions covered a wide range of reseach and demonstration projects on new methods of waste treatment and showed an increasing emphasis on in-plant process changes to reduce or eliminate liquid waste flows. Several projects concerned with treatment to permit recycling of wastes were presented.

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REPORT ON FIRST COMMERCIAL EVALUATION OF DRY CAUSTIC PEELING OF CLINGSTONE PEACHES (2)

by

Herbert E. Stone (1)

INTRODUCTION

Del Monte Corporation, in cooperation with the Environmental Protection Agency under Grant Project No. 12060 HFY, investigated the commercial feasibility of using the dry caustic peeling process to remove chemically softened peach peel and to retain it in a manner which would allow its disposal as a solid material. This process uses the principle of gently wiping the major portion of peel from the peach halves with a series of uniquely designed soft rubber discs which rotate and tumble the fruit. New equipment, specifically designed for this purpose, facilitates the peeling. A series of fresh water sprays -- applying a minimum amount of water -- removes any residual peel remaining after the wiping action.

Clingstone peach is a major crop with an annual production exceeding 30 million cases. Being a seasonal fruit, it cannot be stored for any length of time. The production period is therefore relatively short, ranging from only a few weeks, in some areas, to a maximum of three months.

The most common commercial peeling process for cling peaches utilizes a dilute sodium hydroxide (caustic) solution to soften the peel. This is followed by large quantities of fresh, potable water applied under high pressure to dislodge and remove the peel and caustic residues. The effluent from this operation frequently contains relatively high amounts of dissolved and undissolved organic materials which do not lend themselves to mechanical removal. Consequently, these wastes comprise a portion of the liquid effluent from the plant.

Disposal of this effluent with the resultant organic and hydraulic loads which may be imposed on municipal or privately owned waste treatment systems has frequently been a serious concern to communities in plant locations, as well as to regulatory agencies.

---

(1)Manager, Environmental Protection, Del Monte Corporation, San Francisco, California

(2)This investigation was supported by funds from the Environmental Protection Agency Water Quality Office under Grant No. 12060HFY.

In response to this concern, the food processing industry has completed a number of research projects whose prime goals have been determining means for reducing:

1) the generation of oxygen demanding substances (BOD, COD, etc.) which are a natural component of the food; and,

2) the use of fresh water in plant or processing areas where product quality and sanitation requirements would not be adversely affected.

One such project was carried out in 1970 under EPA (formerly Federal Water Quality Administration) Research and Development Grant No. 12060 FQE entitled "Dry Caustic Peeling of Tree Fruit for Liquid Waste Reductions". (Reference #1) Under this project, the National Canners Association Western Research Laboratory in Berkeley, California, with the assistance of the Western Utilization Research Laboratory of USDA in Albany, California, demonstrated the feasibility for removing caustic softened peach peel with the aid of rapidly rotating, soft rubber discs, retaining the solid peel separate from the liquid waste stream and removing the small amounts of residual peel and chemical residue with markedly reduced volumes of fresh water.

On the basis of these pilot scale results, Del Monte Corporation offered a proposal to the Environmental Protection Agency to design, construct and permanently install equipment which would afford a commercial demonstration of the feasibility for peeling cling peaches, removing and retaining the peel as a solid waste and significantly reducing the volume of fresh water normally used during this phase of the preparation of peaches for canning.

EPA Research and Development Grant No. 12060 HFY was awarded on April 1, 1971 for the purpose of partially supporting the implementation of this proposal. Del Monte Corporation Plant No. 3, located in San Jose, California, was selected as the site for this demonstration installation.

Commercial size equipment was designed by Del Monte engineers and constructed in a company-owned machine shop and on the site by plant personnel. Details of the design and installation are appended to the final report which will be available shortly from EPA. (Reference #6)

Installation of the experimental peeler was completed during the early summer of 1971. A brief test period under production conditions indicated a need for adjustments and minor modifications of the peeler and a conveyor belt. Continuous, three-shift operation of the experimental peeler was initiated on August 10, 1971. The evaluation continued through September 17, the close of the 1971 cling peach canning season.

The commercial size equipment was patterned after the NCA-USDA model and was scaled in size to peel 10-12 tons per hour of pitted cling peach halves equal to approximately 25% of the total plant production.

A sub-project in the evaluation of the new peeling process for cling peaches was the biological treatment of water used as a final rinse after peel removal. Concentrated waste water was segregated from all other waste flows and piped directly to an existing high rate trickling filter biological treatment system which had been used in previous studies and is described in greater detail in other reports. (References (2)(3)) Work under this phase of Project 12060 HFY was supervised and conducted by personnel from the National Canners Association Western Laboratories in Berkeley, California.

CONVENTIONAL PEELING

In the conventional peeling method, (Figure No. 1) pitted peaches are turned so that the pit cavity is facing downward (termed "cup down") on a LaPorte metal (link chain) conveyor belt immediately prior to entering a partitioned tank. In the first section of the tank, peach skins are sprayed with a dilute solution of hot sodium hydroxide (caustic). The conveyor carries the fruit through the second steam heated holding section where chemical action on the skins is completed. In the last section, the fruit is carried under a series of high pressure water sprays where peel and caustic residue are removed and flushed into floor drains for disposal. In the operation at Del Monte's Plant No. 3, as many as 20 banks of sprays may be used to complete the peeling. However, only the final six spray headers apply fresh water with the remainder divided into groups of sprays using recycled rinse water in a countercurrent manner.

Control of chemical peeling is achieved by adjustments of the sodium hydroxide concentration, temperature of the solution and speed of the conveyor to allow for reaction time of the hydroxide solution on the skin. If necessary, a food grade wetting agent may occasionally be added to the caustic solution to facilitate removal of tenaciously adhering peels on some varieties of fruit.

Following the final series of fresh water sprays, the peach halves are again inverted so that the pit cavity is facing up as the fruit is conveyed past another visual inspection station where defects or other lower quality peaches are removed for trimming, diversion to an alternate style of product or discarded. Defects include pit fragments, peel residues, blemishes, imperfect halves, green fruit, etc.

DRY CAUSTIC PEELING

Peach halves peeled by the experimental dry caustic method (Figure 2) are subjected to the identical sodium hydroxide solution concentration, temperature and holding period as the conventional method described above. However, prior to rinsing with water, peach halves are diverted from the LaPorte conveyor onto a cross conveyor rubber belt which provides distribution over the full width of the dry caustic peeling unit, described in greater detail below. From the peeling unit, peaches slide down a short chute into a tank of water from where they are elevated by a link chain slat conveyor to another conveyor for return to the inspection belts, described previously.

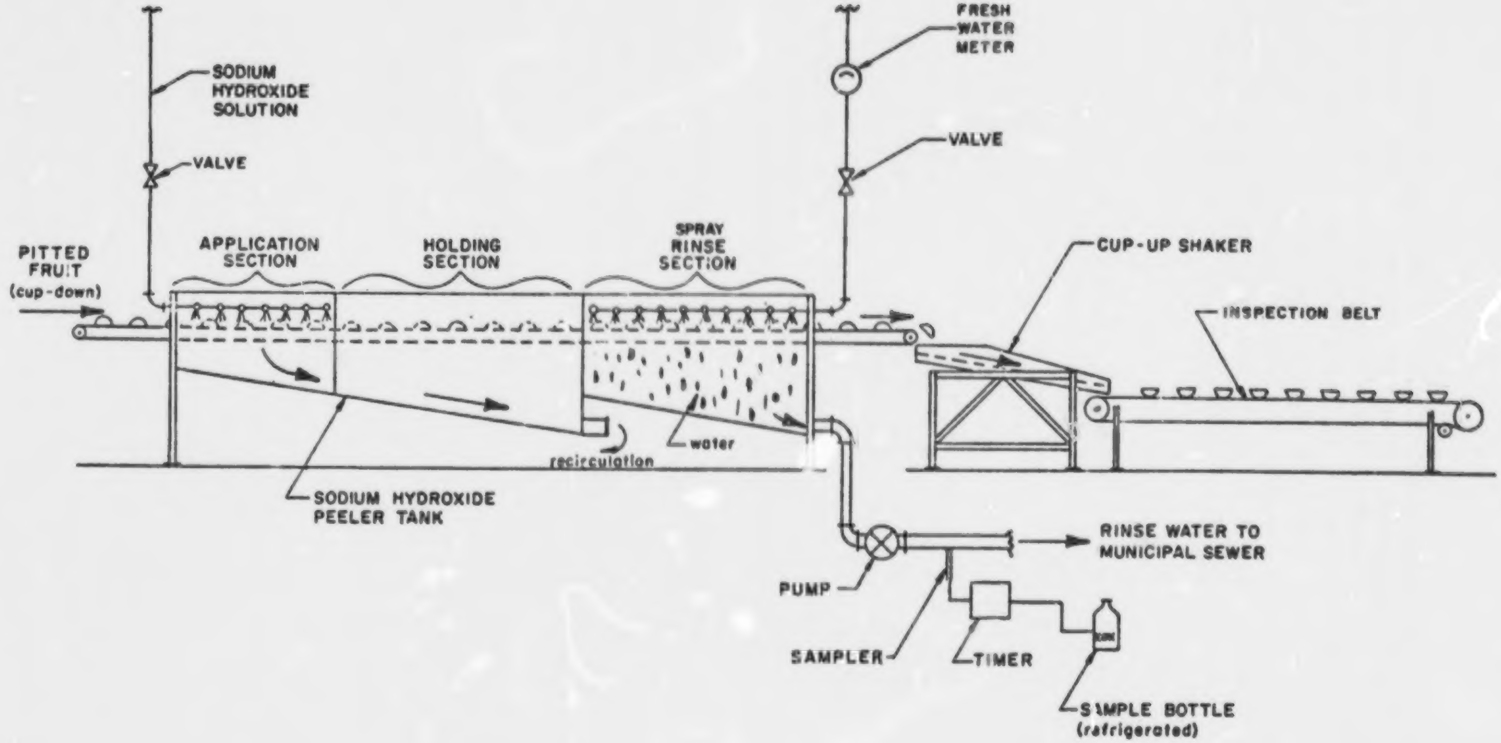

SODIUM HYDROXIDE SOLUTION
VALVE
FRESH WATER METER
VALVE
PITTED FRUIT (cup-down)
APPLICATION SECTION
HOLDING SECTION
SPRAY RINSE SECTION
CUP-UP SHAKER
INSPECTION BELT
recirculation
water
SODIUM HYDROXIDE PEELER TANK
RINSE WATER TO MUNICIPAL SEWER
PUMP
SAMPLER
TIMER
SAMPLE BOTTLE (refrigerated)

Figure 1. Schematic-conventional liquid caustic peeler

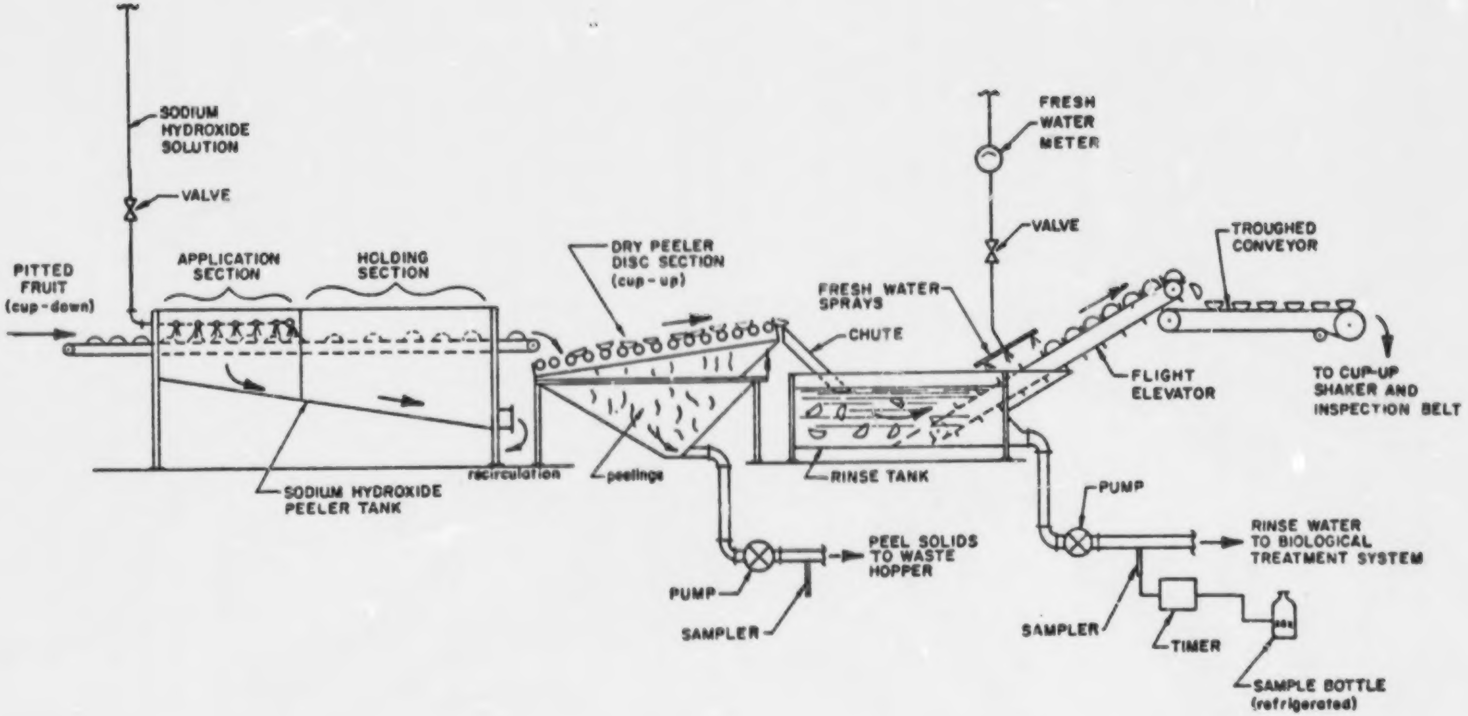

SODIUM HYDROXIDE SOLUTION
VALVE
PITTED FRUIT (cup-down)
APPLICATION SECTION
HOLDING SECTION
SODIUM HYDROXIDE PEELER TANK
recirculation
DRY PEELER DISC SECTION (cup-up)
peelings
PUMP
SAMPLER
PEEL SOLIDS TO WASTE HOPPER
CHUTE
FRESH WATER SPRAYS
RINSE TANK
FRESH WATER METER
VALVE
FLIGHT ELEVATOR
TROUGHED CONVEYOR
TO CUP-UP SHAKER AND INSPECTION BELT
PUMP
RINSE WATER TO BIOLOGICAL TREATMENT SYSTEM
SAMPLER
TIMER
SAMPLE BOTTLE (refrigerated)

Figure 2. Schematic-dry caustic peeler

Once past this inspection station, no attempt is made to keep "dry" and conventionally peeled peaches separate or to differentiate in any subsequent grading, preparation, canning or processing operation.

DEMONSTRATION EQUIPMENT

The dry caustic peeling unit consists of a frame -- six feet wide by ten feet long -- mounted on adjustable legs. A series of 39 stainless steel shafts are mounted across the six-foot dimension. Specially designed, soft rubber discs (food grade rubber) are mounted on each shaft. A chain drive from a 7-1/2 H.P. vari-speed U. S. Motor to sprockets at the end of each shaft provide positive rotation of the discs. The rotating action cleans the peach halves and transports them across the top of the peeler.

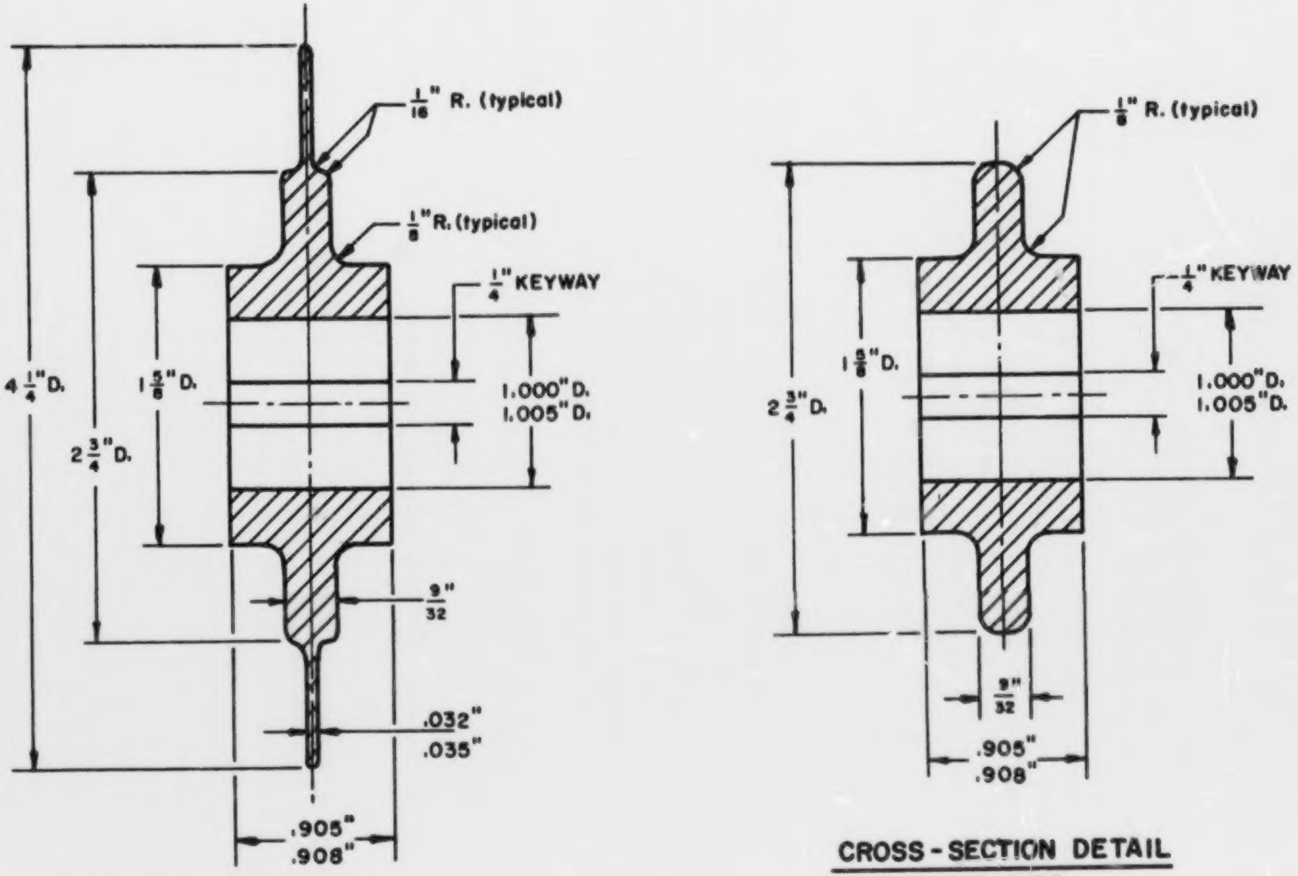
Peeling is achieved by the gentle abrasion of discs rotating at a speed of approximately 325 rpm. Discs are of two types. The larger 4-1/4 inch diameter size incorporates a flexible flanged edge which gently removes the softened peel on peaches traveling in a single layer on the tops of the discs. The smaller 2-3/4 inch diameter stub discs are mounted on specific shafts and strategically placed to invert peach halves which may turn over into a "cup down" position as a result of the tumbling action. It is, of course, necessary to expose the peel portion of the peach to the abrasive action of the discs.

Figure No. 3 is an engineering diagram of the two types of discs. More complete details regarding configuration, dimensions and placement of discs may be found in the engineering drawings appended to the EPA report on Project 12060 HFY (Reference 6).

Discs and spacer sections between discs are cast as one piece in the mold. A projection or "key" in the center hole is also an integral portion of each disc. The "key" fits into a slot on the shaft, thereby achieving positive drive of the disc. This contrasts with the previous year's pilot model which used plastic spacers between the discs and depended upon friction to drive the discs.

As noted above, movement of the peach halves is achieved by discs rotating in the same direction as the flow of fruit. Duration of time on the peeler unit is controlled by adjustment of the height of the discharge end over the feed end. The discs, in effect, are pushing the peach halves up a slight incline. A 17-18 inch rise over the ten foot length from feed to discharge end of the peeler was found optimum for the varieties of peaches processed by the plant during the 1971 canning season.

Peel and caustic residues fall between the rotating rubber discs into a conically shaped tank from where they are pumped through a separate 4" diameter pipe into a large hopper in the plant yard. (The waste from this hopper is combined with solid wastes from other fruit preparation operations and is hauled by truck to an approved land disposal site.)


$\frac{1}{16}$" R. (typical)
$\frac{1}{8}$" R. (typical)
$\frac{1}{4}$" KEYWAY
$4\frac{1}{4}$" D.
$1\frac{5}{8}$" D.
$2\frac{3}{4}$" D.
1.000" D.
1.005" D.
$\frac{9}{32}$"
.032"
.035"
.905"
.908"
$\frac{1}{8}$" R. (typical)
$\frac{1}{4}$" KEYWAY
$1\frac{5}{8}$" D.
$2\frac{3}{4}$" D.
1.000" D.
1.005" D.
$\frac{9}{32}$"
.905"
.908"

CROSS-SECTION DETAIL
FLANGE DISC

CROSS-SECTION DETAIL
STUB DISC

Material: Black Rubber - 50 Durometer-Food Grade

Figure 3. Rubber Disc Detail

The chemically softened peel material, as it is removed from the peach halves, is a viscous slurry or semi-solid which can be pumped easily by commercially available conventional cement type pumps. In this project, the primary collection tank was drained by manually starting the pump 2-3 times per hour. Each draining represents approximately 60 cubic feet of peach peel slurry.

Three (3) manifolds of fresh water sprays, mounted above the link chain elevator conveyor, remove peel and caustic residues and provide the only fresh water rinsing necessary on the "dry" peeled fruit. These sprays also serve as make-up water for the tank into which the fruit slides following the peeler section. Four (4) spray nozzles, each nozzle delivering approximately one gallon per minute of fresh water, are mounted on each manifold and positioned to achieve full coverage of the elevator conveyor width. An automatic sensing device maintains the proper level of water in the tank following the peeler. Rinse water from this tank is piped to the biological treatment system being tested by NCA personnel as a sub-project of the peeling evaluation.

ANALYTICAL PROGRAM

An extensive analytical program was conducted to evaluate the effectiveness of the dry caustic peeler for removing the peel and retaining the solid material as a separate entity. Characteristics of the waste rinse waters from the "dry" method were compared with those from conventional peeling methods. Figure No. 4 is a schematic of the sampling points for these parameters. Table I lists analyses conducted in the Del Monte Research Center and the NCA Laboratory and the schedule for each. The characteristics of peel and rinse water are those deemed most significant.

As indicated in the schedule, rinse water characteristics were determined on both 24-hour composite samples collected daily and on a series of hourly grab samples collected on two operating days each week during the project period. The schedule was adjusted to allow for initiation and completion of laboratory analyses during the normal work week insofar as possible.

Automatic sampling devices, installed on rinse water discharge lines from both peelers, were activated by timers which opened a valve allowing air to "push" a measured quantity of rinse water from each sampling station through plastic tubing into individual plastic bottles inside a conventional household style refrigerator, located adjacent to the dry caustic peeling unit. An eight-ounce sample, drawn once per hour, was selected as the quantity and frequency of sub-sample for each composite. The reasonably uniform volume of water used in this operation and the similarly uniform flow of peaches did not require more frequent sampling or necessitate attempts to catch subtle variations. Approximately 2-1/2 gallons of composite sample were collected daily from each line. The composite bottle was shaken thoroughly before transferring approximately one gallon to another clean plastic bottle for transport to the Del Monte laboratory. The larger composite sample bottles were then drained, rinsed several times with fresh water, drained again and returned to the refrigerator for collection of the next 24-hour composite sample.

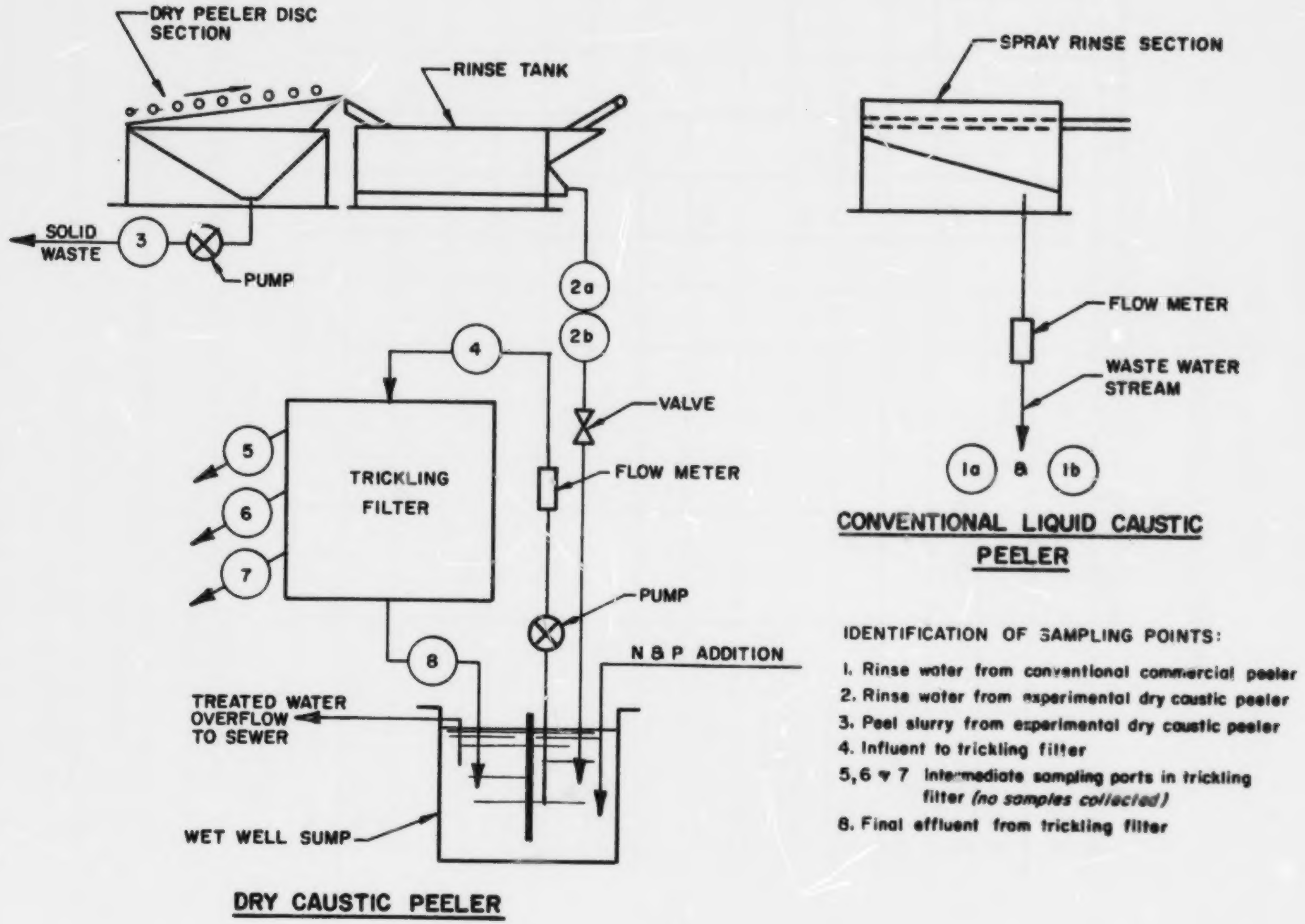

DRY PEELER DISC SECTION
RINSE TANK
SOLID WASTE
3
PUMP
2a
2b
4
VALVE
5
6
7
TRICKLING FILTER
FLOW METER
PUMP
8
N & P ADDITION
TREATED WATER OVERFLOW TO SEWER
WET WELL SUMP
DRY CAUSTIC PEELER
SPRAY RINSE SECTION
FLOW METER
WASTE WATER STREAM
1a & 1b
CONVENTIONAL LIQUID CAUSTIC PEELER
IDENTIFICATION OF SAMPLING POINTS:
1. Rinse water from conventional commercial peeler
2. Rinse water from experimental dry caustic peeler
3. Peel slurry from experimental dry caustic peeler
4. Influent to trickling filter
5,6 & 7 Intermediate sampling ports in trickling filter (no samples collected)
8. Final effluent from trickling filter

Figure 4. Schematic diagram of sampling points

TABLE I - ANALYTICAL PROGRAM

EPA Project - 12060 HFY

Chemical Analysis Required/Sampling Station

	Sampling Stations(1)									
Analyses	1a	1b	2a	2b	3	4	5	6	7	8
BOD_5 (Total)	24C		24C			8C	8C	8C	8C	24C
BOD_5 (Soluble)			24C							24C
COD (Total)	24C	G	24C	G		8C	8C	8C	8C	24C
COD (Soluble)			24C							24C
Total Solids					8C					
Suspended Solids	24C	G	24C	G		8C	8C	8C	8C	24C
Volatile Suspended Solids	24C		24C							24C
Kjeldahl Nitrogen	24C		24C			8C				24C
Nitrite - Nitrogen			24C							
Nitrate - Nitrogen			24C							
Total Phosphate	24C		24C			8C				24C
Ortho Phosphate										24C
Alkalinity (Total)	24C	G	24C	G						
pH	G	G	G	G	G	G	G	G	G	G
Dissolved Oxygen			G							G
Temp. ($^\circ$C)	G		G							G

Footnotes:

(1) Sampling stations are described on following pages and are identified on attached schematic diagram.

24C refers to a 24-hour composite sample which is composited with time during an operating day.

8C refers to an 8-hour composite sample which is composited with time during an operating shift.

G refers to a random grab sample collected once during an operating day for all sample stations except stations 1b & 2b. For stations 1b & 2b, grab samples are to be collected hourly throughout an operating shift with the analysis required on each individual grab sample.

All samples analyzed at the Del Monte laboratory were on fresh material which had been refrigerated for 24 hours or less. Samples were stored in an insulated container during the approximately one hour automobile drive from plant site refrigerator to Research Center laboratory bench.

Peel loss on the fruit for both "dry" and conventional peeling methods was determined by comparing weights for a random selection of 100 peach halves, before exposure to the sodium hydroxide solution, and another 100 randomly selected halves after peeling and rinsing. Peach halves from each peeling method were weighed by trained plant personnel, approximately every half hour throughout the operating day during the duration of the demonstration project.

For clarification, it should be noted that the plant has two completely separate, but identical, conventional peach peelers. During this project, one peeler was used as the "control" for evaluation of conventional rinse water characteristics, water volume measurements and peel loss determinations. Discharge of rinse water from this peeler was mixed with other liquid waste streams from the plant.

A portion of the plant's second peeler was used for this demonstration project and only those peaches and rinse waters which were associated with the experimental unit are included in the data and discussion. Approximately 25% of the plant production (10-12 tons per hour) was peeled by the dry caustic method.

With the exception noted below, all analytical procedures were in accordance with those listed in "Methods for Chemical Analysis of Water and Wastes - 1971 Edition" as prepared by the Water Quality Office of EPA. The BOD procedure as outlined in "Standard Methods for the Examination of Water and Wastewater" - 13th Edition, was followed.

Interference of natural pectin in the fruit prevented use of the conventional methods for separating soluble and suspended or colloidal fractions of matter in the wastewater samples. Consequently, pretreatment of the samples was deemed necessary prior to determining soluble BOD and soluble COD. A series of experiments developed the following procedure:

> Wastewater samples were filtered through diatomaceous earth, followed by filtration through Whatman No. 42 filter paper and ultimately, centrifuging at 2,000 rpm for 20 minutes. The resultant supernatant was reasonably clear and considered suitable for soluble BOD and soluble COD determinations.

Composite samples for analysis of peel characteristics were made by combining hourly collections of a uniform quantity of peel slurry into a single one gallon container. This container was held inside a refrigerator until transfer to the Del Monte laboratory the following morning, along with composite and hourly samples of rinse water. (There was, of course, no comparable solid waste sample from the conventional peeling method, as in the latter instance, all peel is flushed into the liquid stream from where it cannot be physically separated.)

Tables II, III & IV summarize results of composite analyses. Results on the series of hourly grab samples may be found in the EPA report on the project. They confirm the composite sample data. (Reference 6)

The sub-project evaluating potential benefits of biological treatment of the rinse water from the dry caustic unit used concentrated waste water segregated from all other liquid streams and piped directly to the treatment system. A full description of the treatment procedure may be found in the EPA report on this project. Briefly, the system that treated the rinse water was an existing high rate trickling filter which had been used in previous studies and is described in greater detail in other reports (References 2 & 3). A schematic diagram of the system is shown in Figure 5.

To provide for a natural up-draft of air through the treatment column, air ports were installed around the base of the tank. Four inch pipe sections were welded around the tank space at 20 degree intervals, making a total of 18 air ports.

The polyvinyl chloride plastic used in the trickling filter is known as Surfpac, a registered trade name of the Dow Chemical Company. Modules of 19x21x39 inches, each with 27 square feet of surface area per cubic foot and a volumetric void ratio of 0.94 were welded in a honeycomb pattern.

A composite 24-hour sample of the effluent from the trickling filter was collected each day. Two hour grab samples of the influent were also taken each day. Both sets of samples were frozen until analyzed at the NCA laboratory. Procedures for solids, nitrogen and phosphorus determinations were those listed in "Methods for Chemical Analysis of Water and Wastes - 1971", prepared by the Water Quality Office of EPA. The BOD procedure, as outlined in "Standard Methods for the Examination of Water and Wastewater", 13 Edition, 1971, was followed. The Jeris method was used to determine COD values. (Reference 5)

Tables VII and VIII summarize analytical data obtained during two sampling periods.

DISCUSSION

Inspection of the data in Tables II and III, IV, V, & VI, supports some of the projections made for this demonstration evaluation of "dry caustic" peeling of clingstone peaches:

1) Removal of the peel and its segregation as a solid waste reduced the pounds of waste per ton of fruit that would otherwise be present in the liquid effluent from the plant.

Table VI summarizes the pH and per cent total solids for 8-hour composite samples of peel waste collected during the demonstration period.

2) Substantial reductions in water volumes required for this operation are possible.

TABLE II

Analytical Data - 24-Hour Composite Samples
Dry Caustic Peeling Process - Cling Peach Rinse Water

Sample No.	COD mg/1	BOD_5 mg/1	BOD/COD	Total Solids mg/1	Suspended Solids mg/1	Volatile Suspended Solids		Total N mg/1	Nitrite N mg/1	Nitrate N mg/1	Total P mg/1	Ortho P mg/1	Alkalinity $CaCO_3$ mg/1	pH
						mg/1	%							
1A	4785	2190	0.46	5345	--	--	--	--	--	--	7.9	--	470	--
2A	7290	3820	0.52	7010	1650	--	--	110.7	--	--	--	--	615	--
3A	8015	5770	0.72	8465	2925	--	--	122.6	--	--	10.0	--	450	4.35
4A	9895	6170	0.62	7825	3550	--	--	156.9	< 0.02	2.8	15.4	0.8	520	4.56
5A	8030	3860	0.48	6800	3630	3470	95.6	108.6	--	--	10.1	--	435	4.55
6A	3435	2890	0.84	4205	1630	--	--	--	--	--	--	--	370	4.90
7A	11,305	8655	0.77	7160	2860	2630	91.2	--	--	--	--	--	595	5.35
8A	5410	--	--	4320	2450	--	--	--	--	--	--	--	480	4.94
9A	5350	--	--	5180	2170	--	--	119.8	< 0.02	0.2	5.0	< 0.1	605	4.89
10A	3725	2405	0.65	3930	1150	--	--	86.2	--	--	2.3	--	475	5.10
11A	3200	2365	0.74	4290	2200	--	--	--	--	--	--	--	620	5.85
12A	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13A	4300	2485	0.58	4470	2300	--	--	108.6	< 0.02	< 0.1	4.9	2.2	540	4.73
14A	4325	2375	0.55	4085	2300	--	--	92.5	--	--	4.9	--	--	4.70
15A	4095	2720	0.66	3990	1650	--	--	--	--	--	--	--	--	4.88
16A	2965	--	--	3895	2310	2170	93.9	118.4	< 0.02	0.2	3.6	1.6	--	4.78
17A	5490	4545	0.83	--	--	--	--	--	--	--	--	--	--	--
18A	2670	2150	0.81	--	2670	2540	95.1	110.4	--	1.0	2.8	0.3	--	--
19A	4820	4000	0.83	--	2850	--	--	116.5	--	--	12.0	--	--	--
20A	5910	--	--	--	2700	2590	95.9	106.5	0.2	0.8	5.2	3.2	--	--
21A	6965	3540	0.51	--	2750	--	--	117.0	< 0.02	< 0.1	6.7	3.0	--	--
Average:	5600	3750	0.66	5400	2430	2680	94.5	113.5	< 0.02	0.7	7.0	1.6	515	4.90

TABLE III

Analytical Data - 24 Hour Composite Samples
Conventional Peeling Process - Cling Peach Rinse Water

Sample No.	COD mg/l	BOD_5 mg/l	BOD/COD	Total Solids mg/l	Suspended Solids mg/l	Volatile Suspended Solids mg/l	Volatile Suspended Solids %	Total N mg/l	Nitrite N mg/l	Nitrate N mg/l	Total P mg/l	Ortho P mg/l	Alkalinity $CaCO_3$ mg/l	pH
1B	1680	860	0.51	2725	675	--	--	36.4	--	--	6.5	--	430	8.91
2B	1305	790	0.61	2165	450	--	--	25.2	--	--	--	--	410	7.62
3B	--	--	--	--	--	--	--	--	--	--	--	--	--	5.70
4B	1445	930	0.64	2600	1250	--	--	35.7	< 0.02	0.2	1.9	0.7	470	6.85
5B	2030	860	0.42	2525	1020	940	92.2	39.9	--	--	3.6	--	410	6.51
6B	1145	795	0.69	2000	525	--	--	--	--	--	--	--	405	7.11
7B	1415	1025	0.72	1910	570	490	90.7	--	--	--	--	--	375	6.92
8B	1180	--	--	2275	1350	--	--	--	--	--	--	--	405	6.80
9B	1335	--	--	2225	425	--	--	35.0	< 0.02	0.3	0.4	0.2	410	8.32
10B	1295	990	0.76	2160	250	--	--	32.2	--	--	1.0	--	460	6.40
11B	1650	1080	0.65	2680	800	--	--	--	--	--	--	--	490	6.59
12B	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13B	2060	1255	0.61	3125	--	--	--	47.6	< 0.02	0.3	2.6	0.6	480	6.21
14B	1170	835	0.71	2100	750	--	--	29.4	--	--	1.7	--	--	6.20
15B	1820	1145	0.63	2540	200	--	--	--	--	--	--	--	--	6.70
16B	3275	--	--	4135	1340	1260	94.0	56.0	< 0.02	0.2	5.4	1.8	--	6.00
17B	--	--	--	--	--	--	--	--	--	--	--	--	--	--
18B	1135	830	0.73	--	700	640	91.1	31.9	< 0.02	0.5	1.8	< 0.1	--	--
19B	905	705	0.78	--	300	--	--	29.1	--	--	1.6	--	--	--
20B	1100	--	--	--	710	620	87.3	22.4	< 0.02	0.1	0.7	0.1	--	--
21B	1435	1080	0.75	--	1000	--	--	35.7	< 0.02	< 0.1	1.0	0.5	--	--
Average	1520	940	0.65	2510	725	790	91.1	35.1	< 0.02	0.3	2.9	0.6	430	6.90

TABLE IV

COMPARISON OF WASTE EFFLUENT STRENGTH ANALYTICAL DATA

		Range(ppm)	Avg.(ppm)
COD			
	Dry Caustic	2670-11,300	5600
	Conventional	910-3275	1520
BOD_5			
	Dry Caustic	2150-8650	3750
	Conventional	700-1260	940
Suspended Solids			
	Dry Caustic	1150-3630	2430
	Conventional	200-1700	780
Total Solids			
	Dry Caustic	3900-8450	5400
	Conventional	1910-4130	2510
Total Nitrogen			
	Dry Caustic	86.16-156.91	110.32
	Conventional	22.42- 47.63	35.14
Total Phosphate			
	Dry Caustic	2.32-15.39	6.98
	Conventional	0.69- 9.25	2.88
Alkalinity			
	Dry Caustic	372-619	514
	Conventional	374-488	430
pH			
	Dry Caustic	4.35-5.85	4.90
	Conventional	5.70-8.90	6.85

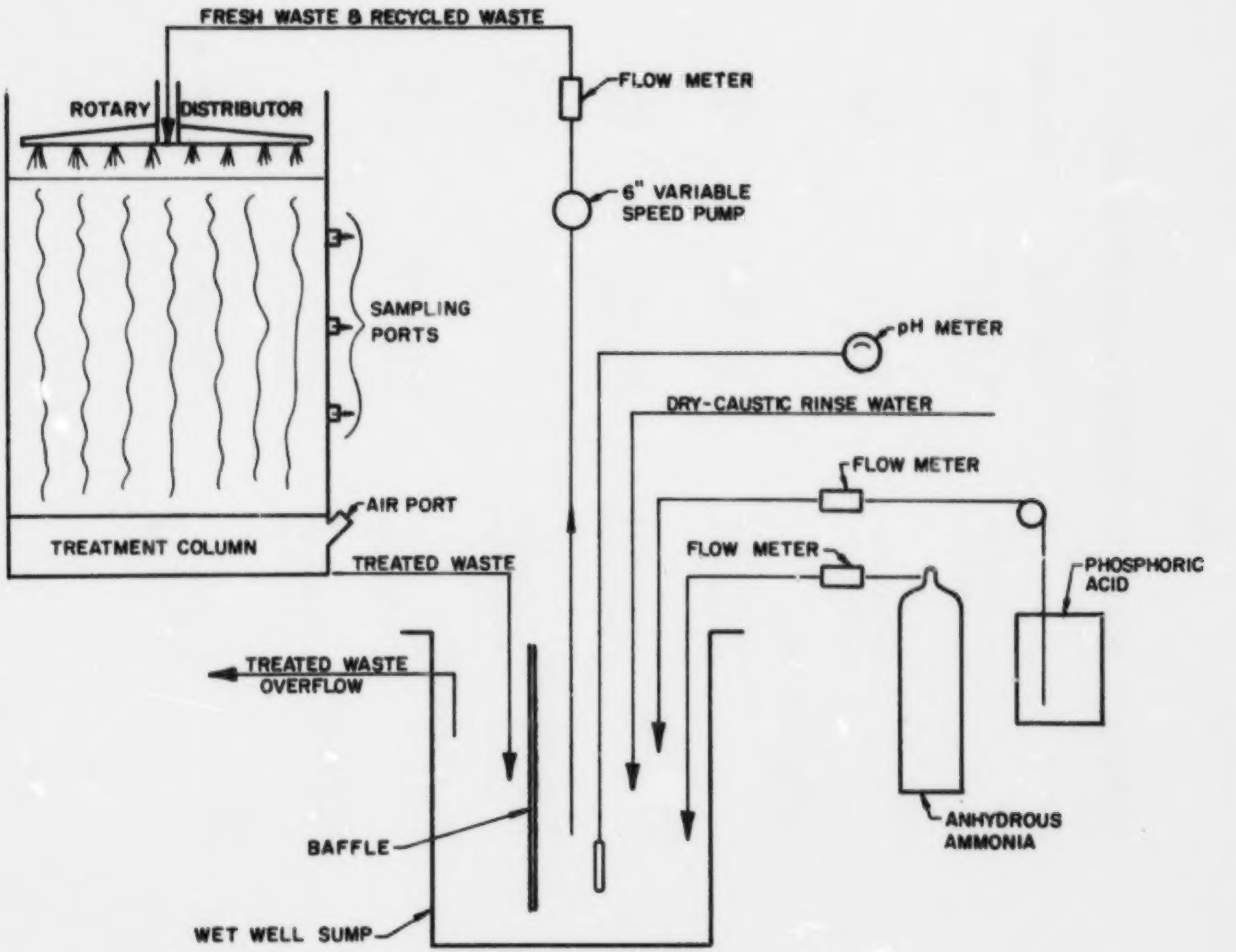

FRESH WASTE & RECYCLED WASTE
FLOW METER
ROTARY DISTRIBUTOR
6" VARIABLE SPEED PUMP
SAMPLING PORTS
pH METER
DRY-CAUSTIC RINSE WATER
FLOW METER
AIR PORT
TREATMENT COLUMN
TREATED WASTE
FLOW METER
PHOSPHORIC ACID
TREATED WASTE OVERFLOW
BAFFLE
ANHYDROUS AMMONIA
WET WELL SUMP

Figure 5. High rate trickling filter system

TABLE V

COMPARISON OF WASTE GENERATION*

Water Use	
Dry Caustic	90 gal/ton
Conventional	850 gal/ton
COD	
Dry Caustic	4.2 lbs/ton
Conventional	10.8 lbs/ton
BOD_5	
Dry Caustic	2.8 lbs/ton
Conventional	6.7 lbs/ton
Suspended Solids	
Dry Caustic	1.9 lbs/ton
Conventional	5.6 lbs/ton
Total Solids	
Dry Caustic	4.0 lbs/ton
Conventional	17.8 lbs/ton

* Average Strengths.

TABLE VI

Analytical Data - 8-Hour Composite Samples (1)
Dry Caustic Peeling Process - Cling Peach Peel Solids

Sample No.	Total Solids (%)	pH
1S	--	--
2S	7.1	--
3S	9.2	--
4S	7.8	--
5S	10.1	10.62
6S	10.2	8.73
7S	8.5	10.50
8S	9.6	10.55
9S	--	9.85
10S	9.0	9.12
11S	10.5	10.32
12S	10.4	9.00
13S	10.7	9.45
14S	10.5	--
15S	11.0	9.50
16S	10.9	9.48
17S	--	--
18S	7.4	--
19S	--	--
20S	11.2	--
21S	11.0	--
Average:	9.7	9.75

Footnote: (1) Peel solids data for day shift only. Spot checks during night shift indicated similar results.

TABLE VII

SUMMARY OF TRICKLING FILTER DATA

Sampling Period - 8/24 - 9/9

Parameter	Influent	Effluent
pH	6.2	5.8
Suspended Solids, ppm	1990	2440
Volatile Suspended Solids, ppm	1920	2360
COD, ppm	5580	4340
BOD,ppm	3490	2940
Nitrogen, Total, ppm	361	415
Phosphorus, Total, ppm	5.9	8.0
Lbs. COD/1000 Ft^3/Day	363	282
Lbs. BOD/1000 Ft^3/Day	227	191

TABLE VIII

SUMMARY OF TRICKLING FILTER DATA

Sampling Period - 9/10 - 9/22

Parameter	Influent	Effluent
pH	5.4	5.3
Suspended Solids, ppm	2620	3100
Volatile Suspended Solids, ppm	2520	2960
COD, ppm	5430	3750
BOD, ppm	3860	2760
Nitrogen, Total, ppm	220	160
Phosphorus, Total, ppm	15.1	13.9
# COD/1000 Ft^3/Day	353	244
# BOD/1000 Ft^3/Day	251	179

Fresh water sprays on the demonstration unit applied a seasonal average of 13 gallons per minute versus approximately 125 gallons per minute for an equivalent amount of fruit in the conventional peeler. These calculate to approximately 90 gallons of water per ton of peaches in the dry caustic peeler and 850 gallons per ton of peaches in the conventional peeler.

3) Slightly lower pH levels for 24-hour composite samples of rinse water from the "dry" peeler indicate removal of caustic residue in the segregated solid peel slurry.

4) Peaches peeled by the "dry" process exhibit slightly greater than average weight loss than those from the conventional peeling method (7.8% vs. 6.6%). However, it is believed the causes for these differences can be corrected. Specifically, the concentration of sodium hydroxide solution is probably higher than necessary for the "dry caustic" peeling method and results in greater softening of the peel and sub-dermal layers than would be necessary in full commercial development of the method. (The sodium hydroxide solution concentration could not be decreased, as 25% of the plant's non-experimental peach production used this same spray section and any significant change in concentration would have resulted in an unsatisfactory peeling under conventional production methods.)

   Another possible factor contributing to the greater peel loss on the "dry" peeled peaches was the additional handling which these halves received. The action of the diversion bar, shearing halves off of the LaPorte belt, undoubtedly removed some flesh from the center portion of the peach. A full-scale commercial unit with a straight flow of fruit would preferably not have this diversion and its consequent abrasive action.

5) During the first series of tests in the trickling filter, COD in the rinse water was reduced 22.2% and the BOD by 15.8%. During the second series, in which nitrogen and phosphorus were added, the COD reduction was 31.0% and the BOD reduction was 28.5%. In terms of pounds of COD or BOD removed per 1,000 cubic feet per day, the filter removed 81 pounds of COD and 36 pounds of BOD when only nitrogen was added. When nitrogen and phosphorus were added, the filter removed 109 pounds of COD and 72 pounds of BOD per 1,000 cubic feet per day.

   It would appear that the improved performance by the trickling filter can be attributed at least in part to the addition of phosphorus as this was the only major difference during the two test runs. The phosphorus content of 5.9 ppm during the first sampling period is considerably less than the recommended ratio of 100 parts BOD to 1 part phosphorus. With the addition of phosphorus, the average concentration of the influent increased to 15.1 ppm and the data show a corresponding increase in BOD removal.

On the basis of removal, the ratios of BOD removed to phosphorus are similar. For the first series, the ratio is 100:1.1 and for the second series, it was 100:1.4. It is speculated that if the phosphorus content were increased above 15 ppm, an even greater increase in the BOD removal might be realized.

Tables VII and VIII are a summary of data collected on the performance of the trickling filter. The summary data is divided into two parts, the first collected when only nitrogen was added to the influent and the second part when nitrogen and phosphorus were added.

Phosphorus contents shown in Tables VII and VIII were determined on unsettled samples. The results between the influent and effluent are similar and do not indicate phosphorus uptake by bacteria as the analysis measures the amounts of total phosphorus in solution as well as in the bacterial mass.

In general, the pH of the rinse water was less alkaline than expected. This fact, combined with the high recycle ratio, lowered the pH below optimum levels for biological treatment and resulted in removing fewer pounds of BOD than anticipated.

Additional analytical data on daily samples may be found in the EPA Report on this project. (Reference 6)

CONCLUSIONS

1) EPA Project No. 12060 HFY demonstrated that the gentle abrasion of rapidly rotating flexible rubber discs can remove major portions of softened peels on clingstone peaches and yield a canning peach of satisfactory quality. Additional work appears desirable to establish the full commercial potential for this method.

2) The project demonstrated that a reduction of almost 90% of fresh water requirements was feasible as a result of the prior removal of peel and caustic residues by the rotating rubber discs. This volume can represent 10% of the total fresh water utilized by some peach canneries.

3) The removal of peach peel and its segregation as a solid waste results in a decrease in the pounds per day of organic matter discharged from the cannery in combination with its liquid effluent.

4) Reduced operating costs may result from use of a "dry caustic" peeler through lowering the costs of water and the operation and maintenance of private or municipal waste treatment facilities.

5) The gentle peeling action of the rotating discs appears to be less abusive to overripe fruit. High pressure rinse water sprays in conventional peelers can damage soft flesh, thereby reducing overall commercial acceptability.

6) Production limitations on certain aspects of the demonstration equipment indicate that modifications are desirable before full commercial potential can be determined.

7) Additional work is needed to fully evaluate the potential for utilizing a high rate trickling filter in treatment of concentrated waste effluents from the peeling of peaches.

ACKNOWLEDGEMENTS

Del Monte Corporation acknowledges the pilot plant evaluations of dry caustic peeling of tree fruits conducted during 1970 by the National Canners Association Berkeley Laboratory in cooperation with the Western Utilization Research Laboratory of USDA in Albany, California. These early efforts and subsequent consultation during the design and development phase of commercial equipment contributed substantially to this demonstration project.

We are further appreciative of the efforts of personnel from the National Canners Association Berkeley Laboratory for their management of the subproject concerned with determining the potential effectivenesss of using a trickling filter biological system for treating concentrated waste water from peach preparation.

We are also indebted to Mr. Kenneth A. Dostal and Mr. Harold W. Thompson in the Pacific Northwest Water Laboratory of the Environmental Protection Agency for their guidance and numerous helpful suggestions in all phases of the project.

The following members of the Del Monte Corporation made significant contributions to the design and development of commercial equipment, supervision of production, and the obtaining and reporting of results.

Research Department:

Dr. Charles F. Niven, Jr. (Director of Research)
Wayne W. Thornburg
Raymond M. Jadarola
Jack G. Allen
Andrew T. Halton
Richard J. Maass
Robert B. Devore
Jo Ruth Wright
Paul Reiche, Jr.
Demetrios Papakonstantino

Production Management:

William L. Hole
Robert E. Crawford
Fred H. Laudenslager
Gene R. Zolezzi
Walter C. Bergstrom
Edward E. Garcia
Robert M. Jorgensen
Richard W. Fish

Engineering Department:

Charles D. Wintermantel
Robert E. McLees
Jack B. Schumate
Favio Franceschi

REFERENCES

1) Report on EPA Project No. 12060 FQE, "Dry Caustic Peeling of Tree Fruit to Reduce Liquid Waste Volumes and Strength" by National Canners Association, Berkeley Laboratory. December 1970.

2) National Canners Association, Berkeley, California, Waste Reduction in Food Canning Operations, Water Quality Office, EPA 12060 -- 08/70.

3) National Canners Association, Berkeley, California. Trickling Filter Treatment of Fruit Processing Waste Waters, Project Number 12969 EAE, Water Quality Office, EPA, Sept. 1971.

4) Chipperfield, P.N.J. Performance of Plastic Filter Media in Industrial and Domestic Waste Treatment, JWPCF 39 1860-1874, 1967.

5) Jeris, J. S. A Rapid COD Test, Water and Waste Engineering 4 (5) 89-91, 1967.

6) Report on EPA Project No. 12060 HFY "Dry Caustic Peeling of Clingstone Peaches on a Commercial Scale" scheduled for publication in 1972.

REDUCED WASTE GENERATION BY ALTERNATE VEGETABLE BLANCHING SYSTEMS**

by

Dr. Jack W. Ralls,* Harry J. Maagdenberg,*
Nabil L. Yacoub,* and Walter A. Mercer*

INTRODUCTION

The heating of vegetables prior to terminal preservation (blanching) is an essential operation for satisfactory final product quality.(1) The blanching treatment produces several desirable changes in the raw vegetables. Primarily, enzymes are thermally inactivated to stabilize the food components against rapid chemical changes. Gases, most importantly oxygen, are displaced from the food during the blanching. For several vegetables, the blanching step results in physical changes in the vegetable which improves subsequent operations such as washing, peeling, or filling into containers. The blanching step may provide a useful removal of certain contaminants on, or in the raw food.

The disadvantages in vegetable blanching using steam or hot-water are loss of nutrients, lower product yields and the formation of large volumes of high strength liquid wastes. Surveys(2) of canneries have shown that an average of 40 percent of total BOD in liquid waste from vegetable processing results from hot-water or steam blanching (shown in Figure 1). New methods of blanching which generate low volumes of liquid wastes would have obvious advantages for environmental protection during vegetable processing.

Blanching methods to replace the traditional steam and hot-water systems and to minimize generation of liquid waste require heat transfer media of controlled water content. Vegetables are 70-92 percent water and during heating exert a partial vapor pressure of water in the gas phase of a closed system. The key to low water volume blanching is heating the vegetable with little or no loss of compositional water to form a liquid waste.

---

*Western Research Laboratory, National Canners Association, Berkeley, California 94710

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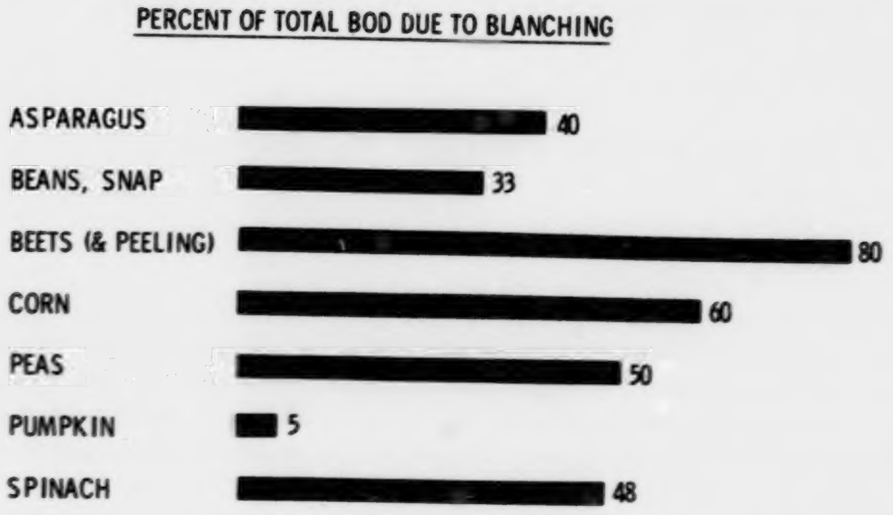

Figure 1. Percent of Total BOD Due to Blanching

The most promising concept for low water volume blanching is the use of microwave energy. Microwaves(3) have the property of internal heating from energy released by reorientation of water molecules. The use of microwave energy has been studied for blanching of a number of vegetables. Recent studies on microwave blanching of corn-on-cob(4), brussel sprouts(5), and potatoes(6) have been reported.

A modification of steam blanching to reduce the volume of liquid waste generated (called IQB) has been reported(7) recently by Lazar, Lund and Dietrich.

A second potential low water volume method of vegetable blanching is the direct use of hot natural gas combustion products in combination with supplemental water vapor as a heat transfer medium.

A unit, which we have called a "hot-air blancher" for direct heating of vegetables was one of four blanching methods compared in this project.

EXPERIMENTAL PLAN

To evaluate the potential usefulness of microwave and hot-air blanching of seven major vegetables commodities, simulators of possible commercial scale units were operated in conjunction with simulators of commercial hot-water and steam blanching equipment.

The microwave unit used in this study was a Varian Model COS 5A Microwave Conveyor shown schematically in Figure 2. The specifications for the microwave blanching unit are tabulated in Appendix A.

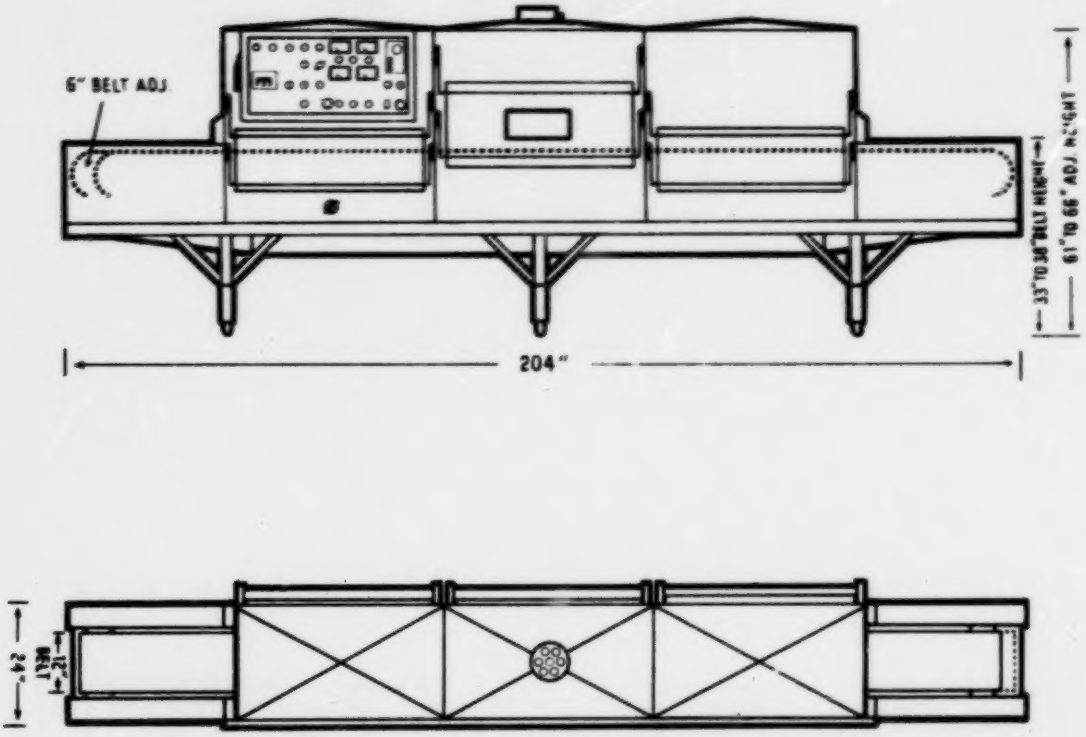

Figure 2. Top and Side View of Microwave Blancher

The hot-air blanching unit was designed by Magnuson Engineers, Inc., and fabricated by Heat and Control Inc. Outline drawings of the hot-air blanchings are shown in Figures 3 and 4. The specifications for the hot-air blanching unit are shown in Appendix B.

The steam and hot-water blanching was simulated in a single unit which was the third stage of the pilot washer provided to the National Canners Association under U.S. Atomic Energy Commission Contract AT (04-3)-536. Outline drawings for the steam and hot-water blancher are shown in Figures 5 and 6. The specifications for the steam and hot-water blancher are listed in Appendix C.

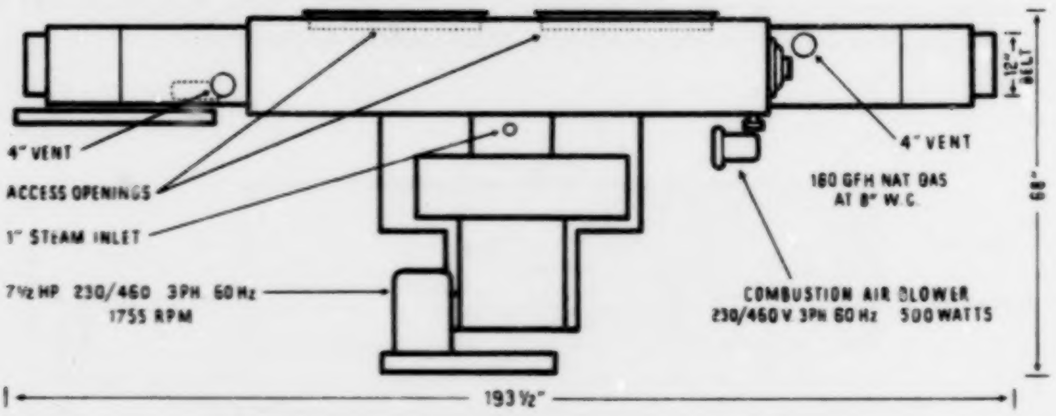
4" VENT
ACCESS OPENINGS
1" STEAM INLET
7½ HP 230/460 3PH 60Hz
1755 RPM
4" VENT
160 GFH NAT GAS
AT 8" W.C.
COMBUSTION AIR BLOWER
230/460 V 3PH 60Hz 500 WATTS
12" BELT
68"
193½"

Figure 3. Top View of Hot-Air Blancher

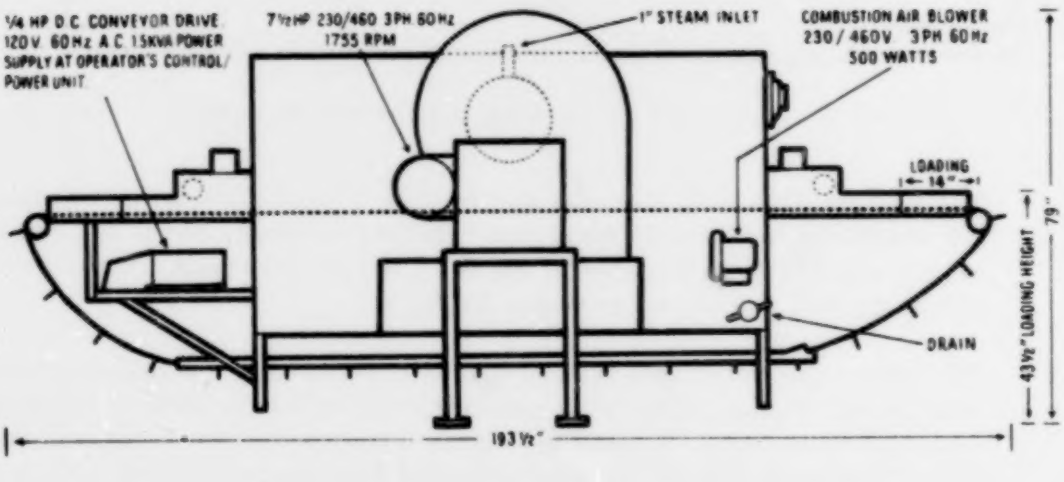
1/4 HP D.C. CONVEYOR DRIVE
120V 60Hz A.C. 1.5KVA POWER
SUPPLY AT OPERATOR'S CONTROL/
POWER UNIT
7½HP 230/460 3PH 60Hz
1755 RPM
1" STEAM INLET
COMBUSTION AIR BLOWER
230/460V 3PH 60Hz
500 WATTS
LOADING
14"
DRAIN
43½" LOADING HEIGHT
79"
193½"

Figure 4. Side View of Hot-Air Blancher

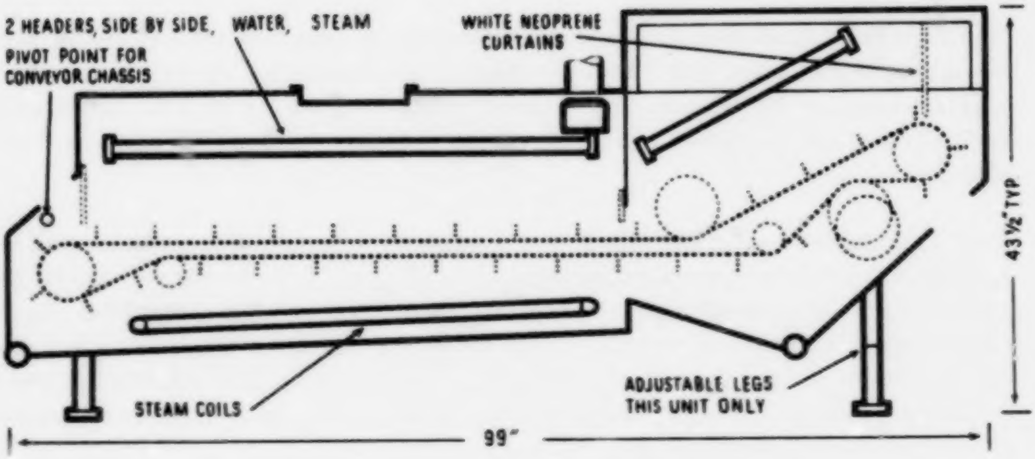
2 HEADERS, SIDE BY SIDE, WATER, STEAM
PIVOT POINT FOR CONVEYOR CHASSIS
WHITE NEOPRENE CURTAINS
43½" TYP
STEAM COILS
ADJUSTABLE LEGS THIS UNIT ONLY
99"

Figure 5. Side View of Water and/or Steam Blancher

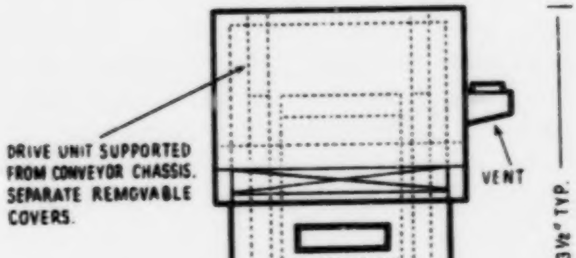
DRIVE UNIT SUPPORTED FROM CONVEYOR CHASSIS. SEPARATE REMOVABLE COVERS.
VENT
43½" TYP.
27"

Figure 6. End View of Water and/or Steam Blancher

The unit was operated as a steam blancher by passing steam into a spray head manifold above the conveyor belt. The unit was operated as a hot-water blancher by circulating a fixed volume of water held in the blancher tank through an automatically controlled (steam heated) tubular heat exchanger.

Raw vegetables were supplied to the project by member canners and were transported by refrigerated truck to the Berkeley Laboratory where the blanching stimulators were installed. A series of short duration experiments were conducted over a range of operating conditions for each blanching unit to determine good operating conditions. The conditions selected for longer duration experiments were based on weight changes, product appearance and residual peroxidase levels.

During the longer duration runs, wastewater samples were collected on a grab and composite basis. The wastewater samples were analyzed for pH, COD and SS. Samples from each of the blanching units were analyzed for significant vitamins and minerals, prepared, (i.e. corn cutting, beet peeling, pumpkin blending and screening) and canned for later quality evaluation.

The quality evaluation of the canned samples had several facets. Sets of samples of each commodity were presented to a laboratory taste panel consisting of 16 tasters. The panel was repeated four times for each sample set for a total of approximately sixty judgements. The sets of four different samples were presented in paper cups marked L, M, N, and O. The panelist was asked to rank the four samples after tasting with 4 denoting the worst flavor and 1 the best flavor. Therefore, if four identical samples were judged, the average score would be 2.50. A scoring sheet used to record the panelist ranking of the samples is shown in Figure 7.

A second evaluation of the canned samples was made by experienced quality graders from the U.S. Department of Agriculture Processed Fruit and Vegetable Inspection Division. The samples were shipped to Stockton, California from where they were distributed by the USDA to individual inspectors. This quality grading developed a number reflecting primarily the appearance of the sample.

An analysis was made of headspace gas in cans representing each blanching variable for each commodity. The method used was essentially that described(8) using gas chromatography.

TASTE PANEL

Please taste and rank samples in order of flavor preference. Take completed scoring sheets and used sample tray to cutting room.

Code	Flavor Ranking 1 = Best; 4 = Worst
L	
M	
N	
O	

Date__________________

Tasters' Initials_____

Figure 7. Scoring Sheet for Taste Panel

The fourth quality evaluation was made by visual examination of washed and dried empty cans from each blanching variable. The cans were scored 4 if badly corroded, 3 if moderately corroded, 2 if slightly corroded and 1 if without visible corrosion.

The fifth quality measurement was made for level of vitamins and minerals(9) significant for each commodity.

EXPERIMENTAL RESULTS

Asparagus Blanching

The green asparagus used was obtained from Washington in two spaced deliveries. The stalks were trimmed by hand to five inch lengths (cutting of the butt ends). The asparagus was blanched in three of the four units; the hot-air blancher was not completely installed while fresh canning asparagus was available. The results from the short duration experiments are tabulated in Table 1.

The results of longer term experiments in asparagus blanching are tabulated in Table 2.

Table 3 tabulates the wastewater volume and characteristics for green asparagus blanching in three experimental units.

Green Pea Blanching

The green peas used for the blanching studies were Alaska variety freezer peas taken from the flume between the third stage prewasher and the hot water blancher at a commercial freezing plant. The experiments were conducted with a single sample of washed peas due to mechanical failure of a rental refrigerated truck on route from Weston, Oregon to Berkeley with the first load of peas. The peas received in the second delivery were loaded at a temperature of 70°F into a section of a refrigerated truck held at 40° F. The peas in the boxes located in the center of the stack did not lose heat rapidly enough to avoid souring. The bulk of the soured peas were sorted out on receipt and only the better quality material used in the blanching experiments. The peas used were of sufficient quality to provide useful measurement of blanching effects except for organoleptic evaluation.

The results of the short duration experiments on blanching of green peas are tabulated in Table 4.

The longer term blanching experiments with green peas are summarized in Table 5.

The wastewater volume and characteristics for blanching of green peas in four experimental units is tabulated in Table 6.

Table 1. Short Duration Blanching Runs for Green Asparagus in Three Experimental Units

Run No.	Blanching Unit	Feed Rate Lb/Hr	Residence Time, Sec	Temp, °F	Peroxidase In-Activation, Slope
Raw	N.A.	N.A.	N.A.	N.A.	0.192
ASP-7	5 kw Microwave	49	673	183	Overblanched
ASP-8	"	240	84	183	0.193
ASP-9	"	300	84	151	0.210
ASP-10	"	160	160	151	0.160
ASP-11	"	105	281	151	
ASP-12	4 kw Microwave	100	398	210	0.010
ASP-13	"	225	130	210	0.285*
ASP-14	3 kw Microwave	225	130	210	0.300*
ASP-15	"	66	281	210	0.135
ASP-16	"	86	206	210	0.175
ASP-17	"	113	160	210	0.175
ASP-32	5 kw Microwave Steam Injection	257	84	144	0.233
ASP-33	"	168	160	144	0.055
ASP-34	"	168	104	144	0.165
ASP-35	"	N.R.	130	144	0.080
ASP-1	Steam	323	135	212	Overblanched
ASP-2	"	331	100	212	0.008
ASP-18	"	400	79	200	0.005
ASP-19	"	267	100	200	0.003
ASP-20	"	268	134	200	0.00
ASP-3	Hot Water	120	227	180	0.007
ASP-5	"	172	147	190	0.004
ASP-21	"	278	90	180	0.04
ASP-22	"	288	66	180	0.04
ASP-23	"	343	52	180	0.10
ASP-27	"	267	90	190	0.007

N.A. = Not Applicable

N.R. = Not Recorded

*Higher values due to lower moisture content of sample.

Table 2. Longer Term Blanching Runs For Green Asparagus in Three Experimental Units

Run No.	Blanching Unit	Feed Rate Lb/Hr	Feed Time, Min	Residence Time, Sec	Temp °F	Product Yield, %	Peroxidase Inactivation Slope
Raw	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.168
ASP-38	5 kw Microwave Steam Injection	110	45	145	144	91	0.06
ASP-36	Steam	180	60	100	200	94	0.00
ASP-37	Hot Water	120	60	90	180	104	0.02

N.A. = Not Applicable

Table 3. Wastewater Volume and Characteristics for Green Asparagus Blanching With Three Experimental Units

Run No.	Blanching Unit	Wastewater Volume, Gal	Sample Collected	COD, mg/l	SS, mg/l	pH
ASP-38	5 kw Microwave Steam Injection	1.3	45 Min Composite	3510	44	6.8
ASP-36	Steam	4.3	60 Min Composite	2490	40	6.7
ASP-37	Hot Water	100	15 Min Grab	51	1	7.7
			30 Min Grab	72	0	7.7
			45 Min Grab	105	0	8.1
			60 Min Grab	128	0	7.4
			60 Min Composite	101	1	7.7

Table 4. Short Duration Blanching Runs For Green Peas in Four Experimental Units

Run No.	Blanching Unit	Feed Rate Lb/Hr	Residence Time, Sec	Temp, °F	Peroxidase Inactivation, Slope
Raw	N.A.	N.A.	N.A.	N.A.	1.75
P-14	5 kw Microwave Steam Injection	138	160	150	0.58
P-16	"	139	130	150	0.51
P-15	0 kw	167	160	150	1.80
P-7	Hot-Air	133	720	225	0.01
P-8	Hot-Air Steam Injection	300	120	220	0.03
P-9	"	300	120	205	0.08
P-10	"	343	120	226	0.18
P-11	"	369	120	237	Overblanched
P-12	"	1200	120	250	0.14
P-1	Steam	N.R.	62	180	0.85
P-2	"	150	90	180	0.02
P-4	Hot Water	274	62	180	0.93
P-5	Hot Water	192	90	185	0.07

N.A. = Not Applicabl

Table 5. Longer Term Blanching Runs For Green Peas in Four Experimental Units

Run No.	Blanching Unit	Feed Rate Lb/Hr	Feed Time, Min	Residence Time, Sec	Temp °F	Product Yield, %	Peroxidase Inactivation Slope
P-17	5 kw Microwave Steam Injection	222	54	160 (15 min) 200 (39 min)	150	98	0.60
P-13	Hot-Air	710	46	120	255	99	0.14
P-3	Steam	180	55	90	180	100	0.013
P-6	Hot Water	208	58			99	0.043
Raw	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1.75

N.A. = Not Applicable

Table 6. Wastewater Volume and Characteristics for Green Peas Blanching With Four Experimental Units

Run No.	Blanching Unit	Wastewater Volume, Gal	Sample Collected	COD, mg/l	SS, mg/l	pH
P-17	5 kw Microwave Steam Injection	4.25	54 Min Composite	54,300	630	4.2
P-13	Hot-Air	0.005	None	N.M.*	N.M.	N.M.
P-3	Steam	4.0	55 Min Composite	41,000	3,700	4.6
P-6	Hot Water	100	15 Min Grab	1,760	113	4.6
			30 Min Grab	3,900	176	4.6
			45 Min Grab	4,550	180	4.7
			58 Min Grab	6,000	192	4.6
			58 Min Composite	3,920	170	4.4

*N.M. = Not Measured

Green Bean Blanching

The green beans used in the short duration blanching runs were picked up at a cannery in Eugene, Oregon and transported to Berkeley in an air conditioned station wagon. The beans were pole beans which had been snipped and size graded. A field run distribution of sizes 1, 2, and 3 were used. The results of the short duration blanching runs for green beans are tabulated in Table 7.

The green beans used for the longer duration runs were picked up in Junction City, Oregon and transported to Berkeley in two air conditioned station wagons. The beans were cut bush beans of number 3 sieve size. The results for the longer term blanching experiments with green beans are tabulated in Table 8.

The wastewater volumes and characteristics from longer term blanching of green beans are tabulated in Table 9.

Corn-on-Cob Blanching

The corn used in the blanching experiments was obtained in Eugene, Oregon on September 8, 1971. The corn was shipped to Berkeley in the husks. Commercial scale corn husking and cutting equipment was loaned to NCA by the Green Giant Company from their plant in Belvidere, Illinois.

Corn was husked and a portion cut for blanching as cut kernels. In the initial run of cut kernels through the hot-air blancher, about one tenth of the feed weight (95 lb) stuck on the wire mesh conveyor belt and caramelization of the starchy liquid adhering to the corn kernels took place. It was not possible to get an accurate product yield (recorded weight was 77 lb). The conveyor belt was cleaned by using hand brushing of the moving belt (at maximum speed setting) with steam injection into the unit and a continuous water spray on the belt at the product discharge end. The cleaning took 27 min and used 34 gal of fresh water. The cleaning wastewater composite had a COD of 17,900 mg/l and a SS of 3,210 mg/l.

The lack of practical blanching of cut kernel corn with the hot-air blancher made it necessary (for comparative purposes) to run all four blanching units using corn-on-cob.

The results of short duration blanching runs on corn-on-cob in the four experimental units are tabulated in Table 10.

The results of longer term blanching of corn-on-cob in the four experimental blanchers are tabulated in Table 11.

Table 7. Short Duration Blanching Runs for Green Beans in Four Experimental Units

Run No.	Blanching Unit	Feed Rate, Lb/Hr	Residence Time, Sec	Temp, ^{o}F	Peroxidase Inactivation, Slope
Raw 3 Sieve Size	N.A.	N.A.	N.A.	N.A.	Optical Density Greater than 2
BN-6	5 kw Microwave Steam Injection	85 3 Sieve Size	281	146	0.41
BN-7	"	111 3 Sieve Size	206	130	0.44
BN-8	"	108 2 Sieve Size	206	130	0.42
BN-9	"	129 2 Sieve Size	180	112	0.53
BN-10	"	120 1 Sieve Size	130	98	0.81
BN-1	Hot-Air Steam Injection	170 3 Sieve	183	220	>1.0
BN-2	"	200 3 Sieve Size	183	250	0.19
BN-3	"	109 3 Sieve Size	303	250	0.03
BN-4	"	150 3 Sieve Size	233	250	0.03
BN-5	"	200 3 Sieve Size	183	250	0.06
BN-11	"	203 2 Sieve Size	136	250	0.12
BN-12	"	300 1 Sieve Size	103	250	0.38
BN-13	Steam	180 3 Sieve Size	217	180	0.25
BN-14	"	172 3 Sieve Size	217	190	0.10
BN-15	"	172 3 Sieve Size	90	190	0.12
BN-16	"	124 2 Sieve Size	217	190	0.18

Table 7. Short Duration Blanching Runs for Green Beans in Four Experimental Units (continued)

Run No.	Blanching Unit	Feed Rate, Lb/Hr	Residence Time, Sec	Temp, ^oF	Peroxidase Inactivation, Slope
BN-17	Steam	138 1 Sieve Size	90	190	0.20
BN-18	"	129 1 Sieve Size	217	190	0.16
BN-19	Hot Water	146 3 Sieve Size	291	190	0.04
BN-20	"	154 3 Sieve Size	182	"	0.05
BN-21	"	142 2 Sieve Size	182	"	0.08
BN-22	"	120 2 Sieve Size	227	"	0.09
BN-23	"	112 1 Sieve Size	182	"	0.08
BN-24	"	100 1 Sieve Size	227	"	0.11

Table 8. Longer Term Blanching Runs For Cut Green Beans in Four Experimental Units

Run No.	Blanching Unit	Feed Rate, Lb/Hr	Feed Time Min	Residence Time, Sec	Temp °F	Product Yield, %	Peroxidase Inactivation Slope
Raw	N.A.*	N.A.	N.A.	N.A.	N.A.	N.A.	Optical Density > 2
BN-26	5 kw Microwave Steam Injection	132	50	206	130	92	0.53
BN-25	Hot-Air Steam Injection	341	60	333	250	82	0.06
BN-27	Steam	193	50	217	190	94	0.07
BN-28	Hot Water	117	60	291	190	98	0.06

*N.A. = Not Applicable

Table 9. Wastewater Volume and Characteristics for Cut Green Bean Blanching With Four Experimental Units

Run No.	Blanching Unit	Wastewater Volume, Gal	Sample Collected	COD mg/l	SS, mg/l	pH
BN-26	5 kw Microwave Steam Injection	2.4	50 Min Composite	1,470	46	6.5
BN-25	Hot-Air Steam Injection	0.043	60 Min Composite	917	88	7.7
BN-27	Steam	4.25	56 Min Composite	5,420	102	6.1
BN-28	Hot Water	100	15 Min Grab	150	1	7.5
			30 Min Grab	200	4	7.3
			45 Min Grab	370	3	7.1
			60 Min Grab	490	10	6.9
			60 Min Composite	330	8	7.3

Table 10. Short Duration Blanching Runs for Corn-on-Cob in Four Experimental Units

Run No.	Blanching Unit	Feed Rate, Lb/Hr	Residence Time, Sec	Temp, °F	Peroxidase Inactivation, Slope
Raw	N.A.*	N.A.	N.A.	N.A.	0.110
CN-4	5 kw Microwave Steam Injection	82	422	142	Overblanched
CN-5	"	100	224	140	0.008
CN-6	"	194	133	140	0.008
CN-1	Hot-Air Steam Injection	400	240	255	0.028
CN-2	"	320	330	255	0.034
CN-3	"	202	390	260	0.005
CN-7	Steam	201	561	195	Overblanched
CN-8	"	172	658	195	Overblanched
CN-9	"	266	435	195	0.020
CN-11	Hot Water	187	373	190	0.04

*N.A. = Not Applicable

Table 11. Longer Term Blanching Runs For Corn-on-Cob in Four Experimental Units

Run No.	Blanching Unit	Feed Rate Lb/Hr	Feed Time Min	Residence Time, Secs	Temp, °F	Product Yield, %	Peroxidase Inactivation Slope
Raw	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.110
CN-14	5 kw Microwave Steam Injection	159	60	224	130	95	0.067
CN-10	Hot-Air Steam Injection	360	60	330	260	98	0.022
CN-15	Steam	220	60	435	195	98	0.040
CN-12	Hot Water	230	47	437	190	96	0.067

The wastewater volumes and characteristics for longer term blanching of corn-on-cob are tabulated in Table 12.

Red Beet Blanching

A mixture of small and medium sized, washed, red beets were picked up in Eugene, Oregon on September 15, 1971 and brought to Berkeley. The results of short duration blanching runs with beets in the four experimental units are tabulated in Table 13. The results of longer term blanching of beets are tabulated in Table 14.

The wastewater volumes and characteristics for longer term blanching of beets are tabulated in Table 15.

Pumpkin Blanching or Wilting

The pumpkins used in the blanching experiments were obtained near Gridley, California on October 19, 1971 and transported whole to the Berkeley Laboratory. The pumpkin was cut by hand into random sized pieces (1 in. square up to 3 in. square) and the seeds removed.

The results of short duration blanching runs for pumpkin are tabulated in Table 16. The results from the longer term blanching experiments with pumpkin pieces are tabulated in Table 17. The wastewater volumes and characteristics for blanching of pumpkin pieces are tabulated in Table 18.

Spinach Blanching

The spinach used in blanching experiments were obtained from Walla Walla, Washington. The spinach received at the cannery on October 27, 1971 was destoned and washed. The washed spinach was packed in plastic lined lug boxes; crushed ice was added to keep the product cool during the transport period. The spinach arrived in Berkeley in excellent condition on the evening of October 29.

The results of short duration runs for microwave and hot-air blanching of spinach are tabulated in Table 19. No short duration runs were made for steam and hot-water blanching because bench scale work done earlier on samples of fresh market spinach had established that complete peroxidase inactivation could be accomplished with a residence time of one minute at 180°F.

The results for the longer term blanching experiments with whole leaf spinach are tabulated in Table 20.

Table 12. Wastewater Volume and Characteristics for Corn-on-Cob Blanching With Four Experimental Units

Run No.	Blanching Unit	Wastewater Volume, Gal	Sample Collected	COD, mg/l	SS, mg/l	pH
CN-14	5 kw Microwave Steam Injection	0.75	60 Min Composite	4,320	73	6.3
CN-10	Hot-Air Steam Injection	0.0024	60 Min Composite	502	1	6.8
CN-15	Steam	3.12	60 Min Composite	9,380	90	6.4
CN-12	Hot Water	110	47 Min Composite	461	4	7.7

Table 13. Short Duration Blanching Runs For Red Beets in Four Experimental Units

Run No.	Blanching Unit	Feed Rate, Lb/Hr	Residence Time, Sec	Temp, °F	Peroxidase Inactivation, Slope
Raw	N.A.	N.A.	N.A.	N.A.	1.140
BT-4	5 kw Microwave Steam Injection	85	224	130	Overblanched
BT-5	"	239	93	130	0.145
BT-6	"	305	53	130	0.210
BT-1	Hot-Air Steam Injection	69	1100	258	Overblanched
BT-2	"	131	625	258	0.073
BT-3	"	170	390	250	0.100
BT-9	Steam	155	330	198	0.04
	Hot Water*	N.A.	480	200	0.04

*Earlier runs with fresh market beets

N.A. = Not Applicable

Table 14. Longer Term Blanching Runs For Red Beets in Four Experimental Units

Run No.	Blanching Unit	Feed Rate Lb/Hr	Feed Time Min	Residence Time, Sec	Temp, °F	Product Yield, %	Peroxidase Inactivation, Slope
Raw	N.A.*	N.A.	N.A.	N.A.	N.A.	N.A.	1.14
BT-10	5 kw Microwave Steam Injection	240	30	93	130	100	0.105
BT-7	Hot-Air Steam Injection	157	60	625	250	94	0.045
BT-8	Steam	142	53	660	195	96	0.038
BT-11	Hot-Water	150	60	510	198	99	0.075

*N.A. = Not Applicable

Table 15. Wastewater Volume and Characteristics for Red Beet Blanching With Four Experimental Units

Run No.	Blanching Unit	Wastewater Volume, Gal	Sample Collected	COD mg/l	SS, mg/l	pH
BT-10	5 kw Microwave Steam Injection	0.50	30 Min Composite	321	47	5.3
BT-7	Hot-Air Steam Injection	0.007	60 Min Composite	1,530	10	7.0
BT-8	Steam	4.75	53 Min Composite	7,240	424	5.0
BT-11	Hot-Water	100	15 Min Grab	165	5	7.0
			30 Min Grab	247	8	7.0
			45 Min Grab	295	19	6.9
			60 Min Grab	617	20	6.8
			60 Min Composite	370	14	7.0

Table 16. Short Duration Blanching Runs For Pumpkin Pieces in Four Experimental Units

Run No.	Blanching Unit	Feed Rate Lb/Hr	Residence Time, Sec	Temp, oF	Peroxidase Inactivation, Slope
Raw	N. A.*	N. A.	N. A.	N. A.	7.43
PM-1	5 kw Microwave Steam Injection	50	680	80	0.64
PM-2	5 kw Microwave Steam Injection	50	680	140	0.13
PM-3	"	150	390	140	0.10
PM-10	Hot-Air Steam Injection	200	330	235-250	1.8
PM-11	"	140	390	250-265	0.10
PM-12	"	65	1100	250-265	0.33
PM-4	Steam	150	766	193	0.002
PM-5	"	224	560	194	0.047
PM-6	"	256	340	196	0.11
PM-7	Hot-Water	400	227	190	7.0
PM-8	"	200	510	192	1.7
PM-9	"	200	510	209	0.033

*N. A. = Not Applicable

Table 17. Longer Term Blanching Runs For Pumpkin Pieces in Four Experimental Units

Run No.	Blanching Unit	Feed Rate, Lb/Hr	Feed Time Min	Residence Time, Sec	Temp, °F	Product Yield, %	Peroxidase Inactivation, Slope
Raw	N.A.*	N.A.	N.A.	N.A.	N.A.	N.A.	7.43
PM-13	5 kw Microwave Steam Injection	132	60	390	140	94	1.22
PM-14	Hot-Air Steam Injection	127	60	625	250-255	86	0.079
PM-15	Steam	140	60	560(32) 650(28)	196	93	0.0057
PM-16	Hot-Water	120	60	510	210	94	0.013

*N.A. = Not Applicable

Table 18. Wastewater Volume and Characteristics For Pumpkin Piece Blanching With Four Experimental Units

Run No.	Blanching Unit	Wastewater Volume, Gal	Sample Collected	COD, mg/l	SS, mg/l	pH
PM-13	5 kw Microwave Steam Injection	2.5	60 Min Composite	6,560	84	6.2
PM-14	Hot-Air Steam Injection	0.005	60 Min Composite	138	1	6.0
PM-15	Steam	4.5	60 Min Composite	10,360	48	6.1
PM-16	Hot-Water	110	15 Min Grab	220	5	7.4
			30 Min Grab	450	15	7.2
			45 Min Grab	780	15	7.0
			60 Min Grab	910	16	7.0
			60 Min Composite	640	10	7.2

Table 19. Short Duration Blanching Runs For Spinach in Four Experimental Units

Run No.	Blanching Unit	Feed Rate, Lb/Hr	Residence Time, Sec.	Temp °F	Peroxidase Inactivation, Slope
Raw	N.A.*	N.A.	N.A.	N.A.	0.72
SP-1A	5 kw Microwave Steam Injection	17	124	140	N.R.**
SP-1B	"	16	[illegible]	140	Overblanched
SP-2A	Hot-Air Steam Injection	N.R.	[illegible]	250	Dried
SP-2B	"	N.R.	183	250	Overblanched

*N.A. = Not Applicable
**N.R. = Not Recorded

Table 20. Longer Term Blanching Runs For Spinach in Four Experimental Units

Run No.	Blanching Unit	Feed Rate Lb/Hr	Feed Time Min	Residence Time, Sec	Temp, °F	Product Yield, %	Peroxidase Inactivation Slope
Raw	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.72
SP-1	5 kw Microwave Steam Injection	38	60	93	140	68	0.034
SP-2	Hot-Air Steam Injection	145	60	164	250	69	0.004
SP-3	Steam	230	26	79	180	91	0.0008
SP-4	Hot-Water	140	30	66	180	104	0.065

N.A. = Not Applicable

Table 21. Wastewater Volume and Characteristics For Spinach Blanching With Four Experimental Units

Run No.	Blanching Unit	Wastewater Volume, Gal	Sample Collected	COD, mg/l	SS, mg/l	pH
SP-1	5 kw Microwave Steam Injection	0.63	60 Min Composite	280	37	5.6
SP-2	Hot-Air Steam Injection	0.003	60 Min Composite	992	1	6.9
SP-3	Steam	6.4	26 Min Composite	4740	206	6.1
SP-4	Hot Water	100	15 Min Grab	192	22	6.4
			30 Min Grab	256	29	6.4
			30 Min Composite	216	35	6.6

The wastewater volumes and characteristics for longer term blanching of spinach with the four experimental units are tabulated in Table 21.

Samples for Quality Evaluation

Canned samples were prepared for each of the seven vegetables studied in this project; a six month storage at 50 - 80°F (ambient temperature of interior storage in Berkeley pilot plant) before examination was part of the project plan.

Taste Panel Results

Only two of the seven vegetables studied in this project were quality evaluated at the time this report was written. The canned samples of green asparagus and green beans were presented to a laboratory taste panel. The results of the taste panel evaluation are tabulated in Table 22.

Vitamin Analyses

The blanched samples and canned samples were analyzed for levels of significant vitamins. The levels of vitamins found in the blanched samples are tabulated in Table 23. The results for the vitamin content of canned samples of asparagus and green beans are tabulated in Table 24. These two commodities were the only two analyzed up to the time this report was written.

The results of analysis of blanched samples for their content of calcium, magnesium, phosphorus and iron where significant are tabulated in Table 25. No analyses for mineral content of canned samples were conducted since the mineral content of the total can contents would not change except for slight increases due to traces of the elements of interest in the water and salt used for canning brine.

The results of headspace gas analysis by gas chromatography for stored canned samples of green asparagus and green beans are tabulated in Tables 26 and 27.

The results for estimates of internal corrosion of cans used for asparagus and green beans as tabulated in Table 28 show no significant effect due to the blanching method used.

Table 22. Taste Panel Evaluation of Canned Samples After Storage For Six Months

Commodity	Cumulative Taste Panel Ranking*
Asparagus	
Microwave	3.1
Steam	2.2
Hot-Water	2.5
Commercial	2.2
Green Beans	
Microwave	2.9
Hot-Air	2.4
Steam	2.5
Hot-Water	2.1

*Best flavor = 1, Worst Flavor = 4

Table 23. Vitamin Levels in Vegetables Blanched in Four Experimental Units

	Vitamin Content, mg/100g					
Commodity	A*	B_1	B_2	B_6	C	Niacin
Asparagus						
Raw	***		0.22	***	19	1.55
Microwave	***		0.19		14	1.82
Steam	***	**	0.20		22	1.46
Hot-Water	***		0.20		18	1.62
S					2.2	0.04
Green Peas						
Raw	***	0.37	0.17			2.10
Microwave	***	0.35	0.17	0.24		2.04
Hot-Air	***	0.38	0.16	0.27		2.14
Steam	***	0.38	0.13	0.32	****	2.07
Hot-Water	***	0.35	0.15	0.24		1.73
S		0.02	0.01	0.05		0.06
Green Beans						
Raw	***	0.07	0.12	0.06	***	0.52
Microwave	***	0.10	0.13	0.05	***	0.65
Hot-Air	***	0.14	0.12	0.04	***	0.76
Steam	***	0.07	0.12	0.05	***	0.59
Hot-Water	***	0.06	0.12	0.05	***	0.51
S		0.01	0.01	0.05		0.18
Corn-on-Cob						
Raw	***	**	0.11	0.18	***	1.41
Microwave	***	**	0.14	0.23	***	2.23
Hot-Air	***	**	0.12	0.16	***	2.06
Steam	***	**	0.11	0.19	***	2.18
Hot-Water	***	**	0.11	0.19	***	1.91
S			0.02	0.04		0.10

S = Standard Deviation (mg/100g)
* Vitamin A in USP units/100 g
** Enzyme used gave poor results, sample used up in other analyses.
*** Analysis not planned due to low level in commodity
**** Vitamin C lost in all samples during storage before analysis.

Table 23. Vitamin Levels in Vegetables Blanched in Four Experimental Units (continued)

Commodity	A	B_1	B_2	B_6	C	Niacin
Red Beets						
Raw	***	***	0.06	***	6.9	0.24
Microwave	***		0.05	***	6.8	0.21
Hot-Air	***		0.07	***	7.5	0.26
Steam	***		0.05	***	5.6	0.20
Hot Water	***		0.04	***	7.9	0.20
S			0.001		0.5	0.02
Pumpkin						
Raw	9630	***	***	***	***	0.49
Microwave	8420	***	***	***	***	0.38
Hot-Air	6760	***	***	***	***	0.59
Steam	13,180	***	***	***	***	0.27
Hot Water	7760	***	***	***	***	0.32
S	400					0.04
Spinach						
Raw	384	***	0.08	***		***
Microwave	696	***	0.13	***	****	***
Hot-Air	702	***	0.14	***		***
Steam	605	***	0.10	***		***
Hot-Water	624	***	0.07	***		***
S	25		0.01	***		***

Table 24. Vitamin Content of Canned Vegetables After Storage for Six Months

	Vitamin Content, mg/100g				
Commodity	B_1	B_2	B_6	C	Niacin
Asparagus					
Microwave	0.05	0.10	***	3.79	0.64
Steam	0.05	0.09	***	3.62	0.76
Hot-Water	0.06	0.11	***	3.62	0.71
S	0.01	0.01		0.05	0.03
Green Beans					
Microwave	0.03	0.05	N.C.	***	0.35
Hot-Air	0.04	0.07		***	0.39
Steam	0.03	0.06		***	0.34
Hot-Water	0.03	0.05		***	0.34
S	0.01	0.001			0.02

S = Standard Deviation (mg/100g)
*** Analysis not planned due to low level in commodity
N.C. = Not complete at time of report

Table 25. Mineral Content of Vegetables Blanched in Four Experimental Units

	Mineral Content, mg/100g			
Commodity	Ca	Mg	P	Fe
Asparagus				
Raw	21.5	15.7	67.0	***
Microwave	22.1	15.5	77.0	***
Steam	22.0	14.4	70.0	***
Hot-Water	20.2	16.3	69.5	***
S	3.1	1.1	5.3	
Green Peas				
Raw*				
Microwave	14.0	28.5	104	1.03
Hot-Air	14.2	29.1	114	1.06
Steam	13.2	28.1	101	1.00
Hot-Water	14.0	28.3	96	1.03
S	4.4	5.1	17.7	0.21
Green Beans				
Raw	40	27	36	1.21
Microwave	46	29	40	1.28
Hot-Air	52	33	48	1.50
Steam	39	26	36	1.19
Hot-Water	41	27	37	1.15
S	7.3	7.9	3.4	0.39
Corn-on-Cob				
Raw	***	***	80.3	***
Microwave	***	***	91.3	***
Hot-Air	***	***	78.5	***
Steam	***	***	92.5	***
Hot-Water	***	***	*	***
S			6.7	
Red Beets				
Raw	***	***	22.7	***
Microwave	***	***	26.0	***
Hot-Air	***	***	26.6	***
Steam	***	***	23.4	***
Hot-Water	***	***	21.2	***
S			2.4	

Table 25. Mineral Content of Vegetables Blanched in Four Experimental Units (continued)

Commodity	Mineral Content, mg/100g Ca	Mg	P	Fe
Pumpkin				
Raw	9.2	6.7	11.6	***
Microwave	8.8	12.9	21.5	***
Hot-Air	13.5	10.9	13.9	***
Steam	10.5	9.6	14.2	***
Hot-Water	9.2	7.2	10.0	***
S	1.3	0.6	1.0	
Spinach				
Raw	62.2	63.5	20.0	3.1
Microwave	86.0	89.5	50.2	3.4
Hot-Air	60.5	65.0	42.4	3.2
Steam	65.0	65.5	42.4	3.3
Hot Water	50.5	49.0	31.0	3.1
S	1.6	1.9	2.4	0.35

S = Standard Deviation (mg/100g)
*Sample lost
*** Analysis not planned due to low level commodity

Table 26. Headspace Gas Analysis of Canned Green Asparagus Stored Six Months

Blanching Unit	Headspace Volume, ml	Percent				
		N_2	CO_2	H_2	Argon + O_2	Original O_2
Microwave	15.4	83.7	7.2	6.5	2.6	20.0
Steam	10.8	93.6	3.9	0.0	2.5	22.5
Hot-Water	8.6	85.8	3.7	2.4	4.0	20.9

Table 27. Headspace Gas Analysis of Canned Green Beans Stored Six Months

Blanching Unit	Headspace Volume, ml	Percent				
		N_2	CO_2	H_2	Argon + O_2	Original O_2
Microwave	28.8	93.1	4.9	0.0	2.0	22.4
Hot-Air	29.1	88.9	5.5	3.7	1.9	21.4
Steam	28.7	92.5	4.8	0.4	2.3	22.2
Hot-Water	24.4	91.4	5.0	1.6	2.0	22.0

Table 28. Estimation of Extent of Internal Corrosion For Cans Used to Store Vegetables For Six Months at 65 - 85°F

Commodity	Extent of Corrosion, Visual*
Asparagus	
Microwave	2
Steam	2
Hot-Water	2
Commercial	3
Green Beans	
Microwave	1
Hot-Air	1
Steam	1
Hot-Water	1

* 4 = severe; 3 = moderate; 2 = slight; 1 = no corrosion

DISCUSSION

Asparagus Blanching

The results on asparagus blanching are incomplete at the present time because the hot-air blancher was not completely installed until after the end of the asparagus harvesting season.

The peroxidase level in green asparagus is readily reduced to low levels by steam or hot-water blanching. Rather long residence times with full five kw power was required to reduce peroxidase levels to about 5 percent of the original level as shown in Table 1 for microwave blanching.

The longer term run for microwave blanching of asparagus resulted in only a 74 percent reduction of peroxidase content. This extent of reduction may be satisfactory for a canned product, but would probably cause off-flavor in frozen samples.

Table 29. Comparison of Long Term Green Asparagus Blanching

Unit	Peroxidase Reduction, %	Wastewater Gal/Ton	COD Lb/Ton	SS, Lb/Ton
Microwave	74	24	.69	9×10^{-3}
Steam	100	53	1.1	1.6×10^{-2}
Hot Water	90	1665	1.3	1.3×10^{-2}

The most important comparison which is made from the results obtained in this project is in the volume and characteristics of wastewater produced. Table 29 tabulates the volume of wastewater, the COD of the wastewater, and the SS content of the wastewater all based on ton of raw product blanched. The volume and strength of the wastewater produced during microwave blanching of green asparagus are much lower than those of steam or hot-water blanching.

Green Pea Blanching

The experiments with green peas were the first to directly compare all four blanching methods. The loss of the first shipment of raw peas due to truck failure limited the number of short duration runs used to establish good operating conditions. The conditions selected for the longer term microwave blanching were not sufficient to accomplish more than a 66 percent reduction in peroxidase content. The conditions selected for the operations of the other blanching units gave greater than 90 percent reduction of initial peroxidase levels. The results from measurement of wastewater generated during the four longer term blanching runs were the first indication of the dramatic reduction in wastewater volume during hot-air blanching. The production of only a few ml of steam condensate during the hot-air treatment of vegetables was found for every commodity studied. On the basis of wastewater volumes only, the hot-air blanching of vegetables is truly a low water volume method.

The very strong liquid waste produced during steam or hot-water blanching of green peas emphasizes the potential improvement of shifting to hot-air blanching as a water pollution abatement practice. The results useful in comparing the four types of blanching are tabulated in Table 30. The COD, SS, and pH of the steam condensate was not measured since the volume was less than that normally used in the determinations.

Table 30. Comparison of Long Term Green Pea Blanching

Unit	Peroxidase Reduction, %	Wastewater Gal/Ton	COD Lb/Ton	SS, Lb/Ton
Microwave	66	43	19.3	.22
Hot-Air	92	1.8×10^{-2}	N.M.*	N.M.*
Steam	99	48	16.6	1.5
Hot Water	98	1,000	32.7	1.4

* N.M. = Not Measured

Green Bean Blanching

The unique part of the short duration blanching experiments with green beans, as tabulated in Table 7, was the use of uniform sizes of raw beans. The beans were taken from size graders at the cannery and were the smallest sizes (1, 2 and 3). The beans were snipped but uncut and would normally be canned without cutting. The time and temperature required for adequate blanching is a function of the size of the vegetable price being blanched. Generally it is desirable to size or maturity grade raw vegetables to obtain optimum blanching conditions. No rigorous study of the effect of sieve size on blanching requirement was made in this project due to lack of time and raw material. The beans used for the longer term blanching runs were cut No. 3 sieve size so the conditions used were selected from short duration experiments which used whole No. 3 sieve size beans.

The data comparing major results of the longer term blanching experiments with green beans are tabulated in Table 31.

Table 31. Comparison of Long Term Green Bean Blanching

Unit	Peroxidase Reduction, %	Wastewater Gal/Ton	COD, Lb/Ton	SS, Lb/Ton
Microwave	89	48	.59	1.8×10^{-2}
Hot-Air	99	.25	2×10^{-3}	2×10^{-4}
Steam	99	47	2.1	4×10^{-2}
Hot-Water	99	1,710	4.7	.11

Corn-on-Cob Blanching

It was expected to blanch the corn as whole kernel corn after cutting from the cob since the bulk of corn for canning and freezing is blanched after cutting. Due to the cut kernels sticking to the belt of the hot-air blancher, it was not possible, within the time limitations, to study whole kernel corn blanching.

There is a substantial production of both canned and frozen corn-on-cob, so the study of corn-on-cob blanching would apply to a commercial product.

The results of the comparison of wastewater volume and characteristics from the four blanching units are tabulated in Table 32. The wastewater volume from the hot-air blancher is several orders of magnitude smaller than those from hot-water and steam blanching. The wastewater from the hot-air blancher is also much lower in COD and SS for each ton of corn blanched.

Table 32. Comparison of Long Term Corn-on-Cob Blanching

Unit	Peroxidase Reduction, %	Wastewater, Gal/Ton	COD, Lb/Ton	SS, Lb/Ton
Microwave	39	9.4	.34	5.7×10^{-3}
Hot-Air	80	1.33×10^{-2}	5.6×10^{-5}	$<1 \times 10^{-6}$
Steam	64	28.4	2.22	2.1×10^{-2}
Hot-Water	39	1,233	4.70	4.1×10^{-2}

Red Beet Blanching

The results obtained with the blanching of small, whole red beets are tabulated in Tables 13-15. The major difference observed with beet blanching compared to the other six vegetables studied was the intense red color of the wastewater produced with each of the four blanching units. The comparison of wastewater volume and characteristics for red beet blanching is tabulated in Table 33. The volume of wastewater produced from the hot-air unit was once again very much lower than that from the three other blanching methods.

Pumpkin Blanching or Wilting

The results of the study of pumpkin blanching are summarized in Tables 16-18. Very good degree of reduction of peroxidase level for the rather large pumpkin pieces was accomplished by the hot-air unit. The results of a comparison of wastewater volume and characteristics of samples from the four blanching units are tabulated in Table 34.

Quality Evaluation

The samples of canned vegetables prepared from the blanched material from each of the four units were stored for six months before any quality examination was made. The storage period was used to allow any slow chemical reactions due to inadequate blanching to show up in deteriorated

Table 33. Comparison of Long Term Red Beet Blanching

Unit	Peroxidase Reduction, %	Wastewater, Gal/Ton	COD, Lb/Ton	SS, Lb/Ton
Microwave	91	8.4	2.2×10^{-3}	3×10^{-3}
Hot-Air	95	8.9×10^{-2}	1.1×10^{-3}	7.4×10^{-6}
Steam	96	76	4.6	.27
Hot-Water	93	1,330	4.1	.16

Table 34. Comparison of Long Term Pumpkin Blanching

Unit	Peroxidase Reduction, %	Wastewater, Gal/Ton	COD, Lb/Ton	SS, Lb/Ton
Microwave	84	38	2.1	2.7×10^{-2}
Hot-Air	99	7.1×10^{-2}	8.2×10^{-5}	5.9×10^{-7}
Steam	99	64	5.5	2.6×10^{-2}
Hot Water	99	1,830	9.8	1.5×10^{-1}

Table 35. Comparison of Long Term Spinach Blanching

Unit	Peroxidase Reduction, %	Wastewater Gal/Ton	COD, Lb/Ton	SS, Lb/Ton
Microwave	95	33	7.8×10^{-2}	1×10^{-2}
Hot-Air	99	3.6×10^{-2}	3×10^{-4}	3×10^{-7}
Steam	99	56	2.2	0.1
Hot Water	91	1430	2.6	0.3

product quality. Also, if any internal corrosion problem was going to occur due to inadequate blanching it would be evident after six months of storage.

There was some concern that the vegetables blanched by microwave or hot-air might contain higher levels of occluded gases than hot-water or steam blanched material. One of the requirements of adequate blanching is the removal of gases from the product so that headspace vacuum would be maintained during thermal processing and storage and excessive oxygen would not cause product deterioration or internal corrosion of the can. Limitation of time did not permit a direct measure of the gas content of vegetable immediately after blanching. Fortunately, analysis of headspace gas in the canned samples is useful to give an indication of the original content of oxygen in the blanched product. The estimate of oxygen in the blanched product at the time of canning can be made by direct measure of the volume and the nitrogen peak in the gas chromatogram of the headspace gas. This estimate assumes that the hot brine used to fill the can displaces gases from the vegetable and that the gases released change the normal gas composition after the container is sealed. The normal fate of oxygen in headspace gas is a reaction with the container to form stannic oxide or autoxidation products of can liner enamels and/or product. The oxygen content of a normal can of vegetables is usally very low after six months of storage. A hypothetical situation will illustrate the potential changes in headspace gas composition at various stages of preparation and storage.

	Total	Percent			
Condition	Volume*	N_2	O_2	CO_2	Argon
Composition of air	N.A.	78.08	20.95	0.03	0.93
Open can + vegetable	20	78	21	0.0	1.0
Occluded gases	5	40	40	20	0
Brine filled can	20	68.5	25.7	5.0	0.75
Closed can	20	68.5	25.7	5.0	0.75
Closed can after 6 month storage	15	91.25	1.0	6.75	1.0

*Calculated at 760 Hg pressure and 0°C temperature

Without knowing precisely the composition of gases occluded in blanched vegetables, it will be generally true for a single set of blanched samples that the higher the residual nitrogen content, the higher the oxygen content of the can at the time of closure. Therefore, the measured value of residual nitrogen content of canned samples stored six months will be a crude index of occluded oxygen in the blanched sample. The results shown in Table 26 indicate that the content of occluded gases in green beans was not significantly different among the material from each of the four blanchers.

A very important quality factor of the blanched vegetables was the taste panel evaluation of flavor. As shown by the results in Table 22 the only unit which shows less prefered flavor are the samples prepared from microwave blanched asparagus and green beans.

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Appendix A

MICROWAVE BLANCHING UNIT SPECIFICATIONS

Microwave frequency	2450 ± 50 MHz
Microwave power (2-2.5 kw power packs)	5 kw
Entrance and exit port size	4 in.high x 12 in wide
Belt	1/4 in.mesh, coated fibreglass
Belt speed	0-20' per min, reversible
Cavity material	Stainless steel
Finish	28 exterior; 4B
Power requirements:	220 V: 3-phase; 60 Hz
Conveyor only	1 kva
Air heaters only	30 kva
Each power pack	5 kva
Air supply	Adjustable 200-600 cfm
Air temperature controllable to 250°F (depending on rate of air flow)	
Water requirements (each power pack)	1.5 gpm at 20 psig/min
Steam	40 psig

Appendix B

SPECIFICATIONS OF HOT AIR BLANCHING UNIT

Length:	16.5 ft
Width:	6 ft 6 in.
Conveyor:	Stainless steel belt in two levels each with flights, 3 in. high, and 12 in. apart
Conveyor width:	12 in.
Conveyor drive:	Variable speed motor with 10 fold speed range
Heater:	Natural gas fired burners Rated at 125,000 Btu/hr
Blower:	3800 standard cu ft/min
Air temperature:	250°F Maximum
Product Capacity:	500 lb/hr

Appendix C

SPECIFICATIONS OF STEAM AND HOT-WATER BLANCHER

Length:	8.5 ft
Width:	18.5 in.
Belt width:	15.25 in.
Material of Construction:	18 - 8 (304) stainless steel
Bearings:	Bronze brushed with grease fittings
Conveyor: chain:	No. 40, extended pitch
Shaft diameter:	1 in.
Drapes:	B-N standard type, 16 GA. mesh 3/16 in. openings with 2.5 in high flights at 6 in. spacing
Drive:	4.9 - 49 rpm, U.S. Varidrive RT. angle, 0.5 hp, 3 phase, 60 cycle
Belt speed:	4 - 40 fpm
Steam coil test pressure:	225 psig

A FIELD STUDY ON THE APPLICATION OF INDIVIDUAL QUICK BLANCHING*

by

Daryl B. Lund**

INTRODUCTION

The preparation of vegetables for preservation by canning, freezing or dehydration results in large volumes of high strength organic waste streams. With increased awareness of the impact of these seasonal streams on the environment and waste treatment facilities, vegetable processors are looking for technologically-effective and economically-feasible methods of treating or reducing these streams. For the purpose of reducing total plant effluent and biological oxygen demand (BOD), attention has focused on the blanching operation. This operation serves several functions including removal of tissue gases, inactivation or activation of enzymes, reduction of microbial load, cleansing of product and wilting of tissue to facilitate packing. These objectives are accomplished by heating the vegetables in either hot water or steam(1). Both hot water and steam blanching produce liquid wastes high in BOD, and both result in loss of water soluble nutrients. Based on data reported by Weckel et al(2) for two Wisconsin canning plants, a 90% reduction in blancher effluent would reduce total plant waste flow by 10 to 20% and, more significantly, reduce total plant BOD by 20 to 50%. The National Canners Association(3) estimated that if a new blanching method were used for the seven vegetables processed in the largest tonnage which reduced waste water strength by 50%, a total of approximately 70 million pounds of BOD and 40 million pounds of suspended solids would be eliminated from treatment plant loadings.

In the abatement of waste water flow and loss of solids from product in canning and freezing plants, a study was initiated in 1970 to design a blanching process which would have a waste water flow of only 10% of a commercial hot water blancher. The project was supported by the University of Wisconsin and the USDA, and was conducted by M. E. Lazar and D. B. Lund at the Western Marketing and Nutrition Research Division, USDA. The project resulted in a new concept of heating foods and the application to blanching was demonstrated$^{(4,5)}$. The process, individual quick blanch (IQB), required further evaluation and, therefore, the Western Laboratory conducted a study utilizing IQB prior to freezing while the evaluation of IQB for blanching prior to canning was conducted in a Wisconsin canning plant. This paper presents the results of the evaluation of IQB as a precanning process.

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**Department of Food Science, College of Agricultural and Life Sciences, University of Wisconsin, Madison.

METHODS

The IQB unit was furnished by the Western Research Laboratory for use in a Wisconsin canning plant. The unit (described by Lazar et al$^{(4)}$) consisted of two insulated chests, one heated by direct steam and the other heated indirectly, and had a capacity of about 300 pounds per hour. The product, taken from the process line just prior to entering the conventional pipe blancher, was distributed in a single layer (approx. 1 lb/ft^2) on a mesh belt moving through the steam chamber. The residence time was such that the mass average temperature of the product was that desired for blanching. The product was then transferred to a much slower moving belt traveling through the second chamber and remained there until blanching was accomplished. The product was hand packed into 303 x 407 cans to a given fill weight, brine and hot water were added and the can was sealed. The cans were inserted into the plant conveying line to go through the continuous retort process.

Initial investigations by Lazar et al$^{(4)}$ showed that the reduction in waste flow from blanching was enhanced by slightly drying the product prior to steaming. Therefore, some of the runs were conducted on the product which was dried by a 5 to 20% weight reduction in an alternating upflow-downflow hot (160-180°F) air drier.

The effluent from the IQB blancher was collected for the entire run (usually 100 pounds of product) and was analyzed for constituents by the Wisconsin Department of Natural Resources Laboratory. Sample analysis included five-day BOD, total solids, suspended solids, total and soluble phosphorous, total organic-, ammonia-, and nitrate-nitrogen, and pH$^{(6)}$.

The "conventional" blanching system used in this canning plant was a pipe blancher. The water usage was monitored by inserting a water meter in the water make-up line and recording daily water requirements. By knowing the daily case pack on that line, the water usage per case could be determined. It should be noted, however, that the value for water usage in this report (gal/case) does not represent the actual effluent flow from the pipe blancher. Besides the make-up line, there is also the direct addition of steam as the heat source for maintaining water temperature and heating the product. For an estimation, approximately 10 pounds of steam would condense for every 100 pounds of product, and, therefore, the actual effluent flow would be about 0.2 gal/case higher than that reported here for pipe blanchers. Water samples for analysis from the pipe blancher were obtained from the dewatering reel overflow and were analyzed in the same manner as those from the IQB unit.

In order to establish the heat-hold times required for the IQB process, preliminary tests were conducted on each vegetable. It was observed that for peas the conventional blanching operation resulted in inactivation of peroxidase and, therefore, inactivation of peroxidase was used as the criterion for establishing the IQB process times. For corn, green beans and lima beans, the pipe blanching operation was carried out in water at 170°F. Thus, the IQB process was chosen so that the final mass average temperature of these products would be 170°F.

To evaluate the effect of the IQB blanching process on the ultimate quality of the canned product, a taste panel was used to compare the IQB to conventionally blanched-canned vegetables after one, three and six months' storage. Difference and preference judgments were used.

In this study the variety of vegetables used were: peas--Alsweet, corn--Midway, green beans--Slim green, and lima beans--unknown. The case equivalence of vegetables is: peas--15.75 lb/case, corn--15.75 lb/case, green beans--13.05 lb/case and lima beans--13.50 lb/case.

RESULTS AND DISCUSSION

Table 1 presents the blanching times used in the current study. It can be seen that the blanching times for the IQB process are considerably shorter than for the conventional pipe blancher, as would be predicted based on heat transfer rates from steam as compared to hot water. However, it should be pointed out that each processor has his own blanching process and that, therefore, the conventional process presented here may actually be longer than necessary.

The characterization of waste water flow, yield of canned product and sensory evaluation for peas are given in Tables 2, 3 and 4, respectively. The column heading, "Drying (%)" refers to the weight reduction accomplished prior to steaming and holding in the IQB process. "Pipe" refers to the conventional pipe blancher.

Table 2 characterizes the waste water flow from IQB and pipe blanchers for peas. Water flow (gal/case) for the pipe blancher is considerably lower than that reported by Weckel et al(2). They reported water usage of 3.38 gal/case, effluent BOD of 8270 ppm and total solids of 0.72% (w/w) for a pipe blancher. Since there are no established guidelines for the water make-up flow in pipe blanchers, it would be expected that there would be large variations in total water flow with accompanying variations in BOD and total solids. Recall, however, that the water usage reported in these tables does not include the water from condensation of the heating steam. As pointed out in the Methods section, this would amount to about 0.2 gal/case.

The can loss reported was calculated by assuming the peas were 20% total solids and, therefore, one pound of pea solids being discharged from the blancher was equivalent to five pounds of peas. IQB without a drying step resulted in a 68% decrease in total blancher effluent. The characteristics of the effluent was not, however, different from

Table 1. Times and Temperatures for Pipe and IQB Blanching

Blanching Method	Peas		Corn		Green Beans		Lima Beans	
	Time (min)	Temp. (°F)	Time (min)	Temp. (°F)	Time (min)	Temp. (°F)	Time (min)	Temp. (°F)
Pipe Blancher	4	195	1.5	170	2	170	4	170
IQB Heat	0.5	212	0.33	212	0.33	212	0.33	212
Hold	0.75	-	0.50	-	1.33	-	1.33	-

Table 2. Characterization of Waste Water Flow from Pea Blanching

% Drying	Water Flow (gal/case)	T.S. (%)	B.O.D. (ppm)	Can Loss (%)
0	0.32	2.33	16700	2.1
6.5	0.09	2.92	15600	1.1
17.2	0.06	3.32	19600	1.0
Pipe	0.76	2.31	15100	4.8

Table 3. Yield of IQB and Pipe-Blanched Canned Peas

% Drying	Overall Can Loss (%)	Overfill (%)
0	2.1	-
6.5	2.0	0
17.2	13.3	5.69
Pipe	4.8	-

the effluent from the pipe blancher; that is, the percent total solids and BOD were approximately equal in both effluent streams. A possible explanation might be that the pipe-blancher effluent is in equilibrium with the pea; that is, the water emerging from pea blanchers would only build up a certain BOD and total solids, and would, from that time on, not increase in BOD or total solids.

As expected, as the surface moisture was removed from the peas the total effluent flow from the IQB unit decreased. The increase in total solids and BOD for the 17.2% Dry-IQB was probably due to the fact that as the steam condensed and ran off the peas, surface solids were washed off. Further addition of water to the surface of the peas would probably have resulted in only diluting the effluent stream.

The yield of peas from pipe and IQB blanchers is given in Table 3. The overall can loss was calculated from the actual weight of peas processed divided by the initial weight of peas. For the 0% Dry-IQB and the pipe blancher the overall can loss will be equal to the can loss expressed in Table 2. However, for the other two IQB processes--6.5 and 17.2% Dry--the overall can loss in this table is greater than that reported in Table 2. This can be explained by the fact that the peas, once dried, did not completely rehydrate when exposed to steam and, therefore, the overall can loss was greater than that calculated on the basis of solids in the blanch water. For the process that was used, approximately 10 pounds of steam would condense for every 100 pounds of product and, therefore, theoretically enough condensed steam would be available to rehydrate the peas up to about 10% drying. Apparently, with the high rate of condensation and the decreased surface tension due to solids on the surface and high surface temperature (212°F), the condensed steam ran off the peas instead of being absorbed. It could be postulated then that the overall can loss figure could be reduced by allowing the dried-blanched peas to soak, thereby reabsorbing the water lost during drying. Or, for our particular case, we should observe a can overfill approximately equal to the overall can loss minus the can loss based on solids in the effluent. Column 3 of Table 3 presents drained weight data for the processes expressed as a percent overfill. The drained weights were determined after one month's storage at 85°F. It can be seen that IQB dried-canned peas did not regain all of the moisture lost during drying even after the retorting operation and one month's storage. This indicates that some of the moisture was irreversibly lost during drying. The irreversible effect of drying on water reabsorption has been discussed elsewhere(7).

The difference and preference sensory evaluation of IQB- compared to pipe-blanched canned peas is given in Table 4. A plus sign indicates that the IQB was preferred over the pipe-blanched canned peas and a minus sign indicates a preference for the pipe-blanched product. The number refers to the level of significance of the difference. It can be seen that the IQB process produces an acceptable canned product except when excessive drying is used. This was to be expected because it was observed that when peas were dried over 7%, the skins started to split and this resulted in visible differences between the pipe

Table 4. Difference and Preference Between IQB and Pipe-Blanched Canned Peas

Drying (%)	Difference and Preference at: 1 month	3 months	6 months
0	N.S.	+ 5	1
6.5	5	- 0.1	+ 1
17.2	- 0.1	- 0.1	- 0.1

Table 5. Characterization of Waste Water Flow from Corn Blanching

Drying (%)	Water Flow (gal/case)	T.S. (%)	B.O.D. (ppm)	Can Loss (%)
0	0.27	2.55	14800	1.33
8.9	0.01	3.14	19900	0.34
11.8	<0.01	1.48	8000	<0.01
18.5	<0.01	5.07	24700	<0.01
Pipe	1.19	2.51	18000	6.28

Table 6. Yield of IQB and Pipe-Blanched Canned Corn

Drying (%)	Overall Can Loss (%)	Overfill (%)
0	1.33	-
8.9	0.34	3.44
11.8	2.90	9.55
18.5	11.20	3.86
Pipe	6.28	-

and IQB blanched peas. These split skins produced a cloudy brine in the IQB product. Based on these results, it does appear that the IQB process with some drying would result in an acceptable canned product while reducing blancher effluent by up to 88%.

The data on corn blanching are presented in Tables 5, 6 and 7. Table 5 shows that IQB with no drying reduced blancher effluent by 77% and drying to 8.9% reduced it by 92% compared to pipe blanchers. Further drying reduced the blancher effluent more drastically to less than 0.01 gal/case of canned corn. The low percent total solids and BOD of the effluent from the 11.9% drying-IQB process were not expected and the only reasonable explanation is that this corn was very mature and very well washed prior to blanching. Comparing the data on the pipe blancher to that of Weckel et al(2) the water usage reported here is much lower with higher percent total solids and higher BOD. Weckel et al(2) reported values of 2.10 gal/case, 1.10% T.S. and 8,420 ppm BOD. The can loss data show that IQB processing results in a 69% decrease in can loss without drying and at least a 98% decrease with extensive drying. These data were calculated on the basis that corn averaged 25% total solids.

Table 6 presents the yield data from the blanching process for corn. As with dried peas, the overall can loss for dried corn was in excess of that calculated on the basis of solids in the effluent. However, dried corn did reabsorb more moisture during steaming in the IQB process than dried peas did. This is evidenced by the fact that the 8.9% Dry-IQB processed corn lost only the solids in the effluent and regained in steaming all of the moisture lost in drying. Similarly, the 11.8 and 18.5% Dry-IQB corn showed greater recovery of moisture than the 17.2% Dry-IQB peas. These results were to be expected based on the fact that with corn there is a cut surface which can be dried and rehydrated much more readily than a surface with a skin such as peas.

Besides reabsorbing the moisture during steaming, corn also absorbed water during retorting and subsequent storage. This is illustrated by the data in Table 6 as percent overfill. The absorption by the 11.8% Dry-IQB corn again was probably due to having overripe corn while that given for the 18.5% Dry-IQB corn may indicate that drying to that extent results in an irreversible skin formation hindering reabsorption of moisture.

Table 7 shows that the IQB processed corn and pipe-blanched canned corn were indistinguishable by sensory evaluation except for the 18.5% Dry-IQB. In that instance, the difference was highly significant with the pipe-blanched product being preferred. This difference was due to the darker color of the IQB corn. This darker color was evident as the corn came out of the dryer. Even though the drying temperature was at or below 180°F, caramelization did take place during the long residence time required for this degree of drying.

Tables 8, 9 and 10 present the results of green bean blanching. IQB without drying and 6.6% Dry-IQB resulted in a decrease in blancher effluent of 86% and 95%, respectively, as shown in Table 8. Unlike peas and corn, the blancher effluent for IQB and the pipe-blancher for green

Table 7. Difference and Preference Between IQB and Pipe-Blanched Canned Corn

Drying (%)	Difference and Preference at: 1 month	3 months	6 months
0	N.S.	N.S.	N.S.
8.9	N.S.	N.S.	N.S.
11.8	N.S.	N.S.	N.S.
18.5	- 1	- 0.1	- 0.1

Table 8. Characterization of Waste Water Flow from Green Bean Blanching

Drying (%)	Water Flow (gal/case)	T.S. (%)	B.O.D. (ppm)	Can Loss (%)
0	0.26	0.47	3250	0.86
6.6	0.09	0.70	5260	0.49
Pipe	1.92	0.94	5900	11.4

Table 9. Yield of IQB and Pipe-Blanched Canned Green Beans

Drying (%)	Overall Can Loss (%)	Overfill (%)
0	0.86	-
6.6	2.3	1.07
Pipe	11.4	-

Table 10. Difference and Preference Between IQB and Pipe-Blanched Canned Green Beans

Drying (%)	Difference and Preference at: 1 month	3 months	6 months
0	+ 0.1	N.S.	1.0
6.6	- 0.1	0.1	- 0.1

beans did differ in their percent total solids and BOD. This can probably be accounted for by the fact that green beans are cut and then blanched. With the large air spaces exposed in the cut green bean, there would be an extended surface area for leaching, and with water blanching the solids would be leached out. Consequently, the percent total solids and BOD are lower for the IQB effluent. With the 6.6% Dry-IQB there was a higher BOD than with the pipe-blancher effluent. This would probably be due to the lower water runoff in the IQB process resulting in higher BOD. With green beans the potential saving to the canner in terms of can loss would be even greater than with peas or corn. There was a 92% reduction in can loss with 0% Dry-IQB blanching. The green beans were assumed to be 10% total solids for this calculation.

The yield of IQB blanched green beans, given in Table 9, shows that even with a 6.6% drying the IQB process is more efficient. Green beans, like corn, reabsorbs a large percentage of the moisture during steaming that was removed by drying.

Table 10 shows that although there appears to be a difference between IQB and pipe-blanched, canned product, there was no preference. With the 6.6% Dry-IQB, the pipe-blanched green beans were preferred but this was due to the sloughing defect observed in the Dry-IQB product. Apparently during drying, the skin separated from the green bean and sloughed during retorting and storage. The 0% Dry-IQB did not exhibit this sloughing.

Lima bean blanching data are presented in Tables 11, 12 and 13. In Table 11, a noticeable figure is the 20.6 gal/case for pipe-blancher water usage. We have no explanation for this other than the possibility that the water control valve was mistakenly turned wide open. Since the water usage was evaluated by gathering water meter readings over a two-week period, there is no doubt about the figure. IQB reduces the blancher effluent by 99% under these circumstances. It would probably be a fair estimate that with lima bean blanching, we would expect water usage in the range of that for the other vegetables tested (0.76-1.92 gal/case).

The high water usage resulted in a blanch water lower in BOD and percent total solids but also afforded more losses due to leaching. The greater leaching loss is illustrated by the large percent can loss. With IQB the can losses were reduced 97% and more than 99.5% for 0% dry and 10.6% Dry-IQB, respectively. Lima beans were assumed to be 32.5% total solids for the can loss calculations.

The yield of lima beans in the IQB process was significantly better than that of the pipe-blanching process. Lima beans, like corn and green beans, reabsorbed during steaming a substantial fraction of the water removed during drying. This was not entirely expected since lima beans, like peas, have a skin. The percent overfill for lima beans was, however, expected to be high since lima beans normally gain weight during retorting and storage.

Table 11. Characterization of Waste Water Flow from Lima Bean Blanching

Drying (%)	Water Flow (gal/case)	T.S. (%)	B.O.D. (ppm)	Can Loss (%)
0	0.27	1.02	6550	0.58
10.6	< 0.01	0.92	6100	<0.01
Pipe	20.6	0.55	3800	21.4

Table 12. Yield of IQB and Pipe-Blanched Canned Lima Beans

Drying (%)	Overall Can Loss (%)	Overfill (%)
0	0.58	-
10.6	1.6	17.8
Pipe	21.4	-

Table 13. Difference and Preference Between IQB and Pipe-Blanched Canned Lima Beans

Drying (%)	Difference and Preference at:		
	1 month	3 months	6 months
0	5.0	- 0.1	N.S.
10.6	0.1	- 0.1	N.S.

The results of the difference and preference testing, Table 13, indicate that after six months' storage there was no difference as preference between IQB and pipe-blanched canned lima beans. At three months' storage there was a large difference and a strong preference for the pipe-blanched canned product. It was noticed that at that time the IQB-processed lima beans appeared to have a large number of free skins in the product. Apparently with longer storage times these differences disappeared.

Table 14 presents information on the characteristics of the effluent flow from IQB and pipe-blanching systems for all four of the vegetables processed. The BOD/T.S. ratio was variable but the average for all the runs on a commodity were not significantly different. The averages range from 0.59/1 to 0.69/1.

The BOD/N/Phos. ratio indicates that of the four vegetables processed, the pea and lima bean blancher effluent could be treated directly without addition of nitrogen or phosphorous. It has been reported that for stabilization of a secondary waste treatment facility, a BOD/N/Phos. ratio of 100/5/1 is adequate. Consequently, with corn and green beans the blancher water could be best treated by combining it with a high nitrogen source prior to secondary treatment.

CONCLUSIONS

The results of this investigation indicate that IQB can successfully be used for blanching vegetables prior to canning. The IQB process results in reduction of blancher effluent by 68 to 99% while maintaining product quality. Specific results include:

1) Peas: Blancher effluent was reduced at least 68% in the IQB process compared to pipe-blanching. Excessive drying of the peas resulted in skin breakage with resulting cloudy brine and loss of product quality.

2) Corn: IQB reduced blancher effluent between 77 and 99%. There was no product quality loss except under high predrying conditions where the product was darker in color than the control.

3) Green Beans: An 86 to 95% reduction in blancher effluent was obtained using IQB. Product quality was comparable to pipe-blanched canned product except when predried. With predrying, sloughing was evident.

4) Lima Beans: Reductions up to 99% were accomplished in the blanching operation using IQB. With drying, the loss of skins seemed to impair product quality.

Table 14. Characteristics of Effluent from Blanching

Product	Method	B.O.D./T.S. (ppm/ppm)	B.O.D./N[a]/Phos.[b] (ppm/ppm/ppm)
Peas	Pipe	0.66/1	100/5.13/1.26
	IQB 0%[c]	0.71/1	100/4.31/1.23
	IQB 6.5%	0.53/1	100/6.15/1.72
	IQB 17.2%	0.59/1	100/3.78/0.99
Corn	Pipe	0.72/1	100/2.08/0.71
	IQB 0%	0.58/1	100/2.17/0.69
	IQB 8.9%	0.63/1	100/1.37/0.66
	IQB 11.8%	0.54/1	100/1.61/0.69
	IQB 18.5%	0.49/1	100/1.33/0.70
Green Beans	Pipe	0.62/1	100/3.84/0.94
	IQB 0%	0.70/1	100/3.49/0.73
	IQB 6.6%	0.76/1	100/2.92/0.68
Lima Beans	Pipe	0.69/1	100/5.63/0.84
	IQB 0%	0.64/1	100/7.11/0.69
	IQB 10.6%	0.66/1	100/2.40/0.72

a. N = Total organic + ammonia + NO_3 - NO_2 - Nitrogen

b. Phos. = Total phosphorus

c. Percent drying prior to steaming in IQB

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WASTE CONTROL IN THE PROCESSING OF SWEET POTATOES

by

N. V. Colston and C. Smallwood, Jr.*

INTRODUCTION

In North Carolina plans are underway to develop a vegetable processing industry to complement existing fresh market outlets. North Carolina grows about one third of the nation's total sweet potato crop and ranks second behind Louisiana in processing. This year three North Carolina plants are actively engaged in processing sweet potatoes. Last year there were four--one being forced to discontinue canning operations because of associated water pollution problems. If the vegetable processing industry is to grow in North Carolina, or perhaps even to continue to exist, new and/or improved methods and technology for coping with its local environmental impact must be developed.

Tabor City Foods, Inc., of Tabor City, North Carolina, processes approximately 45 percent of the State's pack. Located in an economically depressed community of 3,000, the plant provides employment for about 500 people and cash-crop outlet for an unknown number of farmers. The plant also contributes the majority of wastes entering the city's outdated sewage treatment facility. The city is presently in the process of building a new sewage treatment facility, which, by necessity, had to be overdesigned to accommodate the canning plant waste. Realizing the associated problems of sweet potato canning, Tabor City Foods sought assistance from North Carolina State University. The industry and the University together developed, sought, and were granted an Environmental Protection Agency Demonstration Grant to help alleviate waste problems, increase plant efficiency, and develop a waste management technology for the sweet potato processing industry.

The project's purpose is to make changes in equipment and operations to demonstrate effective water and wastewater management in sweet potato processing. The project encompasses waste abatement and water use throughout the plant from fresh water intake through pretreatment. The specific objectives are:

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*Civil Engineering Department, North Carolina State University, Raleigh, N. C.

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1) Install and/or modify a dry caustic peeling process and demonstrate its effectiveness for water and waste reduction.

2) Install and demonstrate wastewaters pretreatment facilities for the reduction of waste loads.

3) Determine the economic implications of the water and waste management techniques demonstrated.

4) Formulate guides for water and wastewater management in sweet potato processing.

The 1971 processing season of September through December was used for preliminary studies and analytical evaluations required to establish bench mark quantities and characteristics of water consumption, waste production, and plant operating procedures. This was necessitated by the lack of information regarding the present "state of the art" of sweet potato processing.

CANNING PROCESS

An outline and description of major sweet potato processing operations are essential for understanding water consumption and waste production characteristics. The major processing steps are:

Receiving and Unloading

Sweet potatoes arrive at the plant in trucks which are unloaded either by a front-end loader or a large "vacuum cleaner-like" apparatus. Some field dirt falls off the potato during the transfer operations.

Washing

The potatoes are conveyed through a reel washer to remove dirt attached to the potatoes.

Preheating

The potatoes are preheated in a water bath of approximately 105° F for a couple of minutes to enchance the action of the lye bath.

Lye Bath

Potatoes are immersed in a boiling 15 percent lye solution for approximately two minutes to facilitate peel removal and reduce manual trimming operations. The greater the peel loss, the greater the waste produced and the less usable product left.

Peel Removal

Peels are removed by a rotary washer which removes most of the softened peel and part of the potato.

Snipping

Large rotary snippers are used to remove roots or strings from sweet potato ends.

Abrasive Peelers

Sandpaper-like counter rotating rollers are used to smooth the potato surface.

Brush Washer

Counter rotating bristle rollers impart a final sheen to the surface of the potato.

Trimming

The freshly peeled potatoes are inspected and manually trimmed. Product not suitable for canning is rejected.

Sizing

A rotating drum with variable size openings separates potatoes by sizes.

Slicing

Large potatoes move through a series of cutting machines which first half and then quarter the potatoes.

Grading

Potatoes on the grading belt are manually checked for size and quality.

Filling

The raw product moves onto a circular hand pack filler with a series of openings around its outer edge. Potatoes are then raked into cans passing below as the circular top rotates.

Syruping

Most canned sweet potatoes are packed in a syrup medium of sugar and water heated to a temperature just below boiling.

Closing

A sealing machine places a lid on each can and applies pressure to seal the can.

Retorts

High pressure steam retorts are used to cook the canned product for varying periods of time, depending on can size, syrup content, and the average temperature of the contents when placed in the retorts.

Cooling

On removal from the retorts, cans are passed through a cooling canal.

Labeling and Packaging

Labels are pasted on cans and the cans are placed in cases for storage and eventual shipment.

Before the existing conventional process could be modified, a season's operating data on the relationship of water usage and waste characterization to plant production had to be established. The existing laboratory at the plant was geared up to make typical sanitary engineering analytical tests, and the laboratory technician was brought to North Carolina State University for a week of intensive training. Necessary equipment, chemicals, and supplies were purchased for the plant laboratory.

The plant installed nineteen (19) water meters to determine unit process use rates. Daily readings were taken of tons of input, operating hours, and daily production. The breakdown of water consumption per ton of sweet potatoes processed and per case of number 2-1/2 cans produced are given in Table 1.

The retorting operations utilizes the largest amount of water (38.8%) of any single operation. There is no substantial amount of organic material in this water. The water utilized for steam generation and syrup production is consumptive in that it is either packed in cans or evaporates.

Analytical quality measurements were made at Tabor City Foods and at North Carolina State University. All procedures were in accordance with the 1971 Environmental Protection Agency Methods for Chemical Analysis of Water and Wastes. In addition, all samples were passed through a twenty-mesh screen prior to analysis at the request of the Environmental Protection Agency. A composite sample consisting of four grab samples were taken at each sampling station each operating day, or as often as feasible. Chemical oxygen demand, settleable solids, temperature, and pH observations were made on each

TABLE 1

Unit Process Water Use in Conventional Sweet Potato Processing

Unit Process	Gal/Ton Input	Gal/Case #2-1/2 Cans	% of Total Water Use
First Washer	79	2.8	3.0
Preheater	15	0.54	0.5
W/D Washer	280	9.9	10.9
Snippers	110	4.0	4.4
Abrasive Peeler	140	4.8	5.3
Brush Washer	96	3.4	3.7
Retort	1000	35.0	38.5
Cleanup	240	8.6	9.5
Cooling	31	1.0	1.1
Boiler Water	415	15.0	16.5
Belt Wetting	130	4.7	5.2
Syruping	36	1.3	1.4
TOTALS	2572	91.0	100.0

sample collected. Biochemical oxygen demand, suspended solids, dissolved solids, nitrogen, and phosphorus measurements were made less frequently. The range and average concentrations of wastes flows for the conventional unit processes are presented in Table 2.

Whole sweet potatoes were studied in the lab to determine the pounds of COD, BOD, carbon, nitrogen, and phosphorus per pound of whole dry weight. The sweet potatoes examined had an average moisture content of 76 percent. One pound of sweet potatoes (dried at 103° C) was found to produce 1.06 pounds COD, 0.49 pound BOD_5, 0.38 pound of carbon, 0.0184 pound of nitrogen, and 0.0016 pound of phosphorus. If the poundage was based on the wet weight of the potato, these figures have to be multiplied by 0.24. This means that for every pound of sweet potato not put in cans and entering a liquid waste stream, one can expect 0.252 pound COD, 0.118 pound BOD_5, 0.091 pound of total carbon, 0.0044 pound of nitrogen, and 0.000384 pound of phosphorus.

The total pounds of BOD_5, COD, total and suspended solids discharged per ton of raw product input from conventional unit processes utilized in sweet potato processing are presented in Table 3. The data presented represents the waste load after passing samples through a twenty-mesh screen. It is interesting to note that the major sources of waste production (synonymous with product loss) are created by peel removal, abrasive peeling, and snipping operations. All figures shown in this table end up in the liquid waste stream.

Studies were undertaken to define and/or identify the mass balance of sweet potatoes through the processing plant. As a result of these investigations, the following information was generated:

1) Raw product studies revealed that 5 percent (100 lbs/ton) of the product when received was field dirt.

2) Solid waste generation studies revealed that 9.5 percent (190 lbs/ton) of raw product, unfit for canning for various reasons, was trucked away for disposal.

3) Product yield studies revealed that 40 percent (800 lbs/ton) was placed in cans and became a saleable product.

4) Liquid waste studies revealed that 160 pounds of solids dried at 103° C were generated per ton of raw product input (Table 3) after screening. Dividing the 160 pounds by 0.24, the percent total solids in a raw sweet potato, gives 680 pounds of solids per ton of raw product input. Or, 33 percent of the raw product ends up in a liquid waste stream.

TABLE 2

Waste Concentrations for Unit Processes Utilized in Conventional Sweet Potato Processing≠

Unit Process	BOD(mg/L) Average	BOD(mg/L) Range	COD(mg/L) Average	COD(mg/L) Range	Total Nitrogen as N(mg/L) Average	Total Phosphorus as P(mg/L) Average
First Washing	990	460-2400	3,700	1300-8900	12	1.1
Preheater	3,700	2400-4500	9,300	4700-14000	45	17.0
Peel Removal	13,000	7800-23000	32,000	10000-45000	320	40.0
Snippers	5,900	2600-8600	16,000	8100-40000	140	23.0
Abrasive Peeling	14,000	7900-20000	22,000	1600-40000	330	50.0
Brush Washer	3,500	1300-4700	6,400	2000-9600	71	9.2
Retort	76	44-110	210	130-260	0	0
Cleanup	2,200	530-6200	3,800	2200-10000	-	-
TOTAL EFFLUENT*	8,600	4000-13000	22,000	12000-31000	210	29.0

≠After 20-mesh screening
*Excluding Retort Waters

TABLE 2 (continued)

Unit Process	Total Solids (mg/L) Average	Total Solids (mg/L) Range	Suspended Solids (mg/L) Average	Suspended Solids (mg/L) Range	Settleable Solids (ml/L) Average	Settleable Solids (ml/L) Range
First Washing	2,100	800-8700	1,200	300-1500	28	6-40
Preheater	8,400	6500-11000	1,600	600-2660	32	5-64
Peel Removal	35,000	12000-48000	7,700	2500-10500	530	350-750
Snippers	13,000	5300-18000	3,800	600-7100	280	75-500
Abrasive Peeling	23,000	6600-36000	4,400	1100-6700	470	60-730
Brush Washer	4,300	2800-8700	1,200	350-4500	74	18-160
Retort	300	260-370	0	0	0	0
Cleanup	2,700	2200-3200	870	630-1100	-	-
TOTAL EFFLUENT*	26,000	7000-67000	3,800	1400-8000	250	60-570

#After 20-mesh screening
*Excluding Retort Waters

TABLE 3

Waste Loads Per Ton of Input for Unit Processes Utilized in Conventional Sweet Potato Processing*

Unit Process	BOD lbs/ton	COD lbs/ton	Total Solids lbs/ton	Suspended Solids lbs/ton
First Wash	0.7	2.4	1.4	0.8
Preheater	0.5	1.2	1.1	0.2
Peel Removal	30.0	75.0	83.0	18.0
Snippers	5.5	15.0	12.0	3.6
Abrasive Peeling	16.0	25.0	26.0	5.1
Brush Washer	2.8	5.1	3.4	1.0
Retort	0.6	1.8	2.5	0
Cleanup	4.4	7.7	5.5	1.8
Miscellaneous	0	6.8	25.1	0
TOTAL EFFLUENT	60.0	140.0	160.0	30.0

*Rounded off and after 20-mesh screening

5) The sum of the percentages accounted for as dirt, solid waste, yield, and liquid waste is 87.5 percent. The remaining 12.5 percent is believed to represent the quantity of sweet potato discharged into the liquid waste stream that will not pass a twenty-mesh screen. All waste samples were passed through a twenty-mesh screen prior to analysis at the request of the Environmental Protection Agency. This would indicate that a total of 45.5 percent (910 lbs/ton) of the raw product enters the liquid waste stream prior to screening. Therefore, all figures presented in Tables 2 and 3 should be adjusted upward by 1.4 (45.5 ÷ 33) to represent waste generation before screening.

A summary of water use, lye consumption, and waste generation per ton and per case of number 2-1/2 cans for conventional sweet potato canning is presented in Table 4.

PROPOSED CHANGES AND PROCESS MODIFICATIONS

The 1971 processing data gathered from Tabor City Foods is believed to represent the current "state of the art" of conventional sweet potato canning technology. Table 4, the characterization summary, dramatically indicates the severity of the problem facing sweet potato canners. Each of these problem areas bears directly on a processor's economic competitiveness and imposes a potential pollutional load on the local environment. A processor, for example, who is able to realize a greater yield, not only has more saleable product for the same expenditure but reduces his cost of waste treatment. A twofold gain!

The purpose of the second year of the EPA demonstration grant is to design, install, demonstrate, and evaluate four techniques of increasing yield, lowering canning costs, and reducing the environmental impact of sweet potato canning. Specifically, four means of assisting the processor and the environment will be demonstrated. These are dry caustic peeling, lye reconditioning, high pressure water system, and pretreatment of waste.

Dry Caustic Peeling

Conventional vat type (hot dip) lye peeling became the major technique of removing the peels of fruits and vegetables during World War II. The simplicity, economy, and labor saving advantages of lye peeling allowed the U.S. to meet the demand for processed fruits and vegetables at a time when there existed acute shortages of labor and materials. The techniques of lye peeling developed during World War II are still used today.

TABLE 4

Characterization Summary of Conventional Sweet Potato Processing*

Parameter	Per Ton	Per Case
A. Liquid ≠		
BOD (lbs)	60	2.1
COD (lbs)	140	5.0
T. Solids (lbs)	160	5.7
S. Solids (lbs)	30	1.0
B. Solid Waste (lbs)	200	7.1
C. Dirt	100	3.5
D. Water (gallons)	2600	92.0
E. Lye (50%) (gallons)	9.2	0.32

*Rounded off

≠After 20-mesh screening

In 1967-68, Graham, Huxsoll, et al, at the USDA's Western Research and Development Division, Albany, California, announced the development of a new method of peeling potatoes. Their dry caustic method was based on the application of infrared heat to lightly caustic treated potatoes followed essentially by mechanical peel removal.

A ten ton per hour infrared peeling system, based on the Graham-Huxsoll model, is scheduled for installation in the Tabor City Foods' plant this summer. The anticipated changes in operating characteristics from application of this new technology are: 1) lower peel loss, 2) lower water consumption, 3) lower lye consumption, 4) increased product yield, and 5) disposal of generated solids as a solid waste.

Lye Reconditioning

The use of a rotary drum filter for reconditioning lye by removing solids and spent lye from the lye vat is expected to reduce the lye consumption by increasing the useful life of the lye.

High Pressure Water System

Through the use of high pressure spray nozzles, equal or superior removal efficiency can be obtained using less water. The use of less water also means waste concentrations will be greater, facilitating easier pretreatment.

Waste Pretreatment

The installation of a vibrating screen followed by a rotary drum filter is expected to reduce the waste load to the municipality and reduce sewer use surcharges. The solids removed by the vibrating screen and rotary drum filter will be disposed of in a sanitary landfill.

The total anticipated effect of new technology utilized in sweet potato processing as opposed to conventional technology is presented in Table 5.

The economic implications of the water and waste reduction techniques demonstrated will be determined for individual processes and for the total plant. Budgeting procedures will be used to determine costs, returns, and changes in net revenue due to the new technology. Economic implications for devising water and waste reduction policies will be determined from a comparative analysis of the cost of inplant water and waste reduction and wastewater treatment costs.

TABLE 5

Anticipated Effect of New Technology Utilization in Sweet Potato Processing as Compared to the Conventional "State of the Art"

Parameter	Conventional Technology	Advanced Technology
Product Yield	40%	45-50 %
Water (gal/ton)	2600	1400-1600
BOD (lbs/ton)	60	10-15
COD (lbs/ton)	140	25-35
Suspended Solids (lbs/ton)	30	1-5
Total Solids (lbs/ton)	160	35-45
Solid Waste (lbs/ton)	200	600-700
Lye Consumption (gal/ton)	9.2	4-7

Guides for water and wastewater management for the sweet potato processing industry will be formulated. The results of this demonstration grant can be used as management guidelines for applications of infrared peeling, lye reconditioning, high pressure water systems, and pretreatment in the sweet potato processing industry.

SUMMARY AND CONCLUSIONS

The conclusions that can be drawn from the first year of the demonstration grant on water and waste management in sweet potato processing are:

1) The saleable product yield utilizing conventional practices of sweet potato canning is 40 percent.

2) The rate of water consumption is 2,600 gallons per ton of raw product input, or 91 gallons of water per case of 2-1/2 cans produced.

3) Conventional sweet potato processing will produce 60 pounds BOD, 140 pounds COD, 160 pounds total solids, and 30 pounds suspended solids per ton of input after twenty-mesh screening.

4) If the sweet potato canning processors are to continue to exist in North Carolina, steps must be taken to increase product yield, lower peel loss, lower water consumption, and significantly reduce the local impact of the waste released from the plants.

RBC TREATMENT OF SIMULATED POTATO PROCESSING WASTES

by

M. W. Cochrane and K. A. Dostal*

INTRODUCTION

This paper summarizes the observations made during the operation of a pilot plant RBC** (Rotating Biological Contactor) for the treatment of simulated potato processing wastes.

The RBC has not been used in the United States for treatment of potato processing wastes, and this project was designed to establish at least the feasibility of this type of treatment.

The objective of this report was to characterize the removal efficiency of the RBC under various organic and hydraulic loadings and other variable parameters independently, which dictated a simulated wastewater be used that was representative of the large variety of potato processing plants.

The study was conducted at the Environmental Protection Agency's, National Environmental Research Center (NERC), Corvallis, Oregon, by members of the National Waste Treatment Research Program.

TREATMENT PLANT DESCRIPTION & OPERATION

The RBC consisted of circular discs mounted on a rotating shaft. As the shaft rotated, the discs rotated, which caused the biological slime on the discs to become submerged alternately in the wastewater and then exposed to the air. In this way, the slime organisms obtained substrate, nutrients, and oxygen which were necessary for aerobic treatment.

Continuous growth of new slime organisms and sloughing off of older organisms caused a dynamic balance to be reached between organic removal and sludge production. The sludge produced in the RBC must then be separated from the liquid and be given further treatment.

The RBC used in this study had the following dimensions and operating data:

Disc diameter	2 ft
Disc thickness	3/8 inch
Disc spacing	1-1/2 inch center to center

---

*Respectively, Sanitary Engineer and Chief, Food Waste Research Section, National Waste Treatment Research Program, National Environmental Research Center, Corvallis, Environmental Protection Agency, 200 S.W. 35th St., Corvallis, OR 97330

**Autotrol Corp., Milwaukee, Wisconsin.

Disc material	expanded polystyrene
No. of discs per stage	5
No. of stages	6
Specific surface area of discs	15 ft^2/ft^3
Disc rotation speed	10 rpm Run No. 1 and 2 and 20 rpm Run No. 3
Drive motor (chain drive)	1/10 hp Run No. 1 and 2 - 1/8 hp Run No. 3
Overall dimensions	63"(L)x25"(W)x28"(H)

Specific surface area was the total surface area of the discs divided by the "shaft-length volume" occupied by the discs. The shaft length was approximately 4 feet.

A photo of the RBC is shown in Figure 1.

Nutrient addition was considered necessary since analyses of influent samples at the start of the project showed at times there was less nitrogen and phosphorus than required to meet the generally accepted 100:5:1 (BOD:N:P) ratios.

Figure 2 is a flow diagram of the treatment plant. Concentrated potato feed was pumped from cold storage (4°C) and joined with a dilution stream of tap water before entering a primary clarifier where the surface settling rate was always less than 300 gpd/ft^2. Settled effluent from the primary clarifier flowed by gravity to stage one of the RBC. A solution of nitrogen and phosphorus nutrients was also pumped to the influent line.

Influent to the RBC in stage one took place at the water surface level while flow between stages 1 and 2, 2 and 3, 4 and 5, and 5 and 6 occurred 3/4 inch above the bottom of the baffles through a 1-1/2 inch diameter hole. Flow from stage 3 to 4 took place through a 1 inch diameter hose on the side of the unit 4-1/2 inches from the bottom. Effluent flow occurred at 3 inches above the bottom through a 1 inch diameter opening.

Disc rotation was counterclockwise when looking from influent to effluent end. Power for rotation was provided by an electric motor, variable speed gear box, and chain drive.

Liquid level in the RBC was controlled at about 8 inches depth by the liquid level control box which also provided a slight flushing action which prevented clogging of the RBC effluent line and subsequent increase in biological solids concentration in the RBC mixed liquor.

Hydraulic detention time studies were conducted using sodium chloride as a tracer and an electrical conductivity meter. Two runs were made under steady state conditions. The first run was at 0.61 gpd/ft^2 hydraulic rate, and the second was at 0.25 gpd/ft^2. Both runs were made using a clean RBC, i.e., no biological growth or wastewater was on the discs or in the mixed liquor.

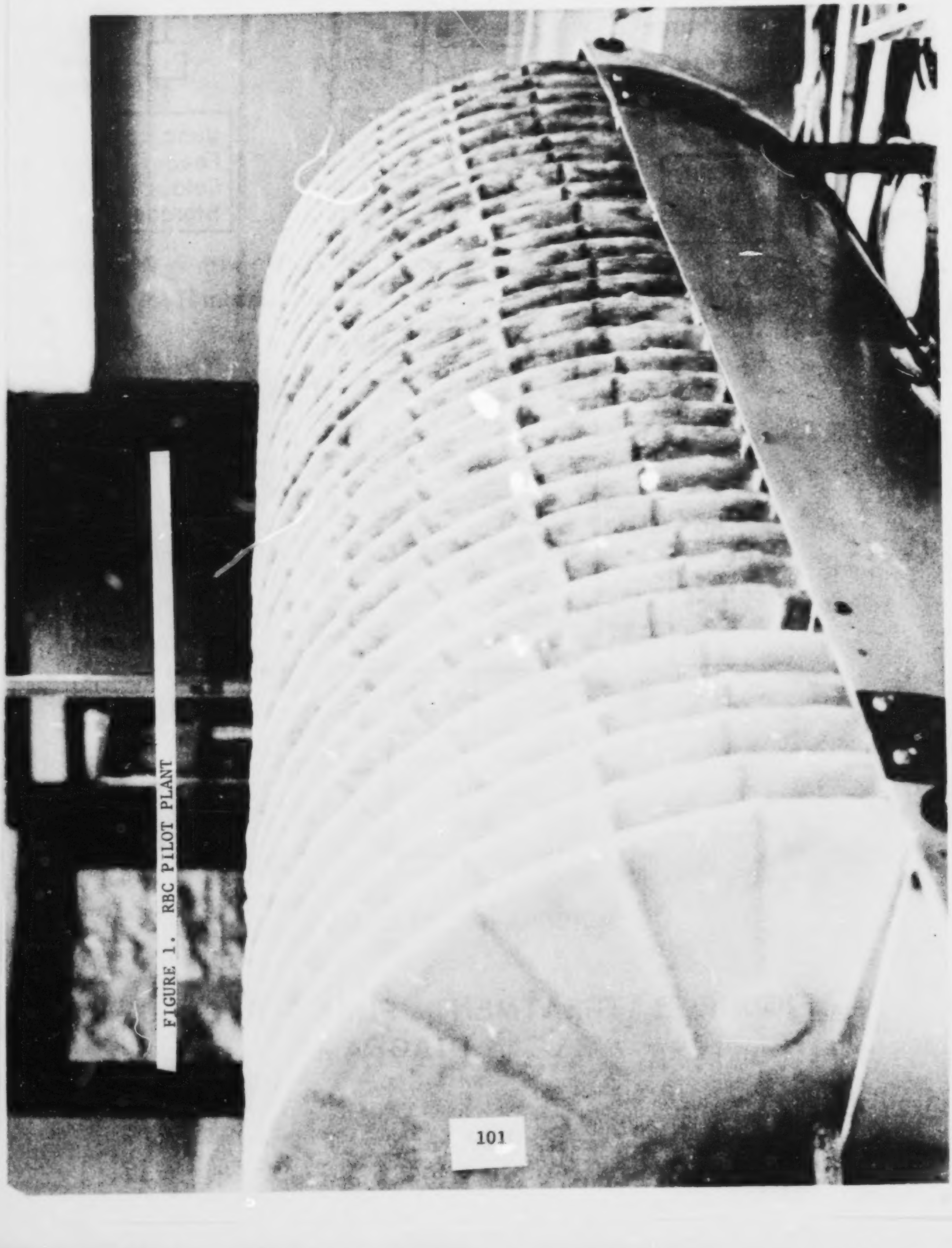
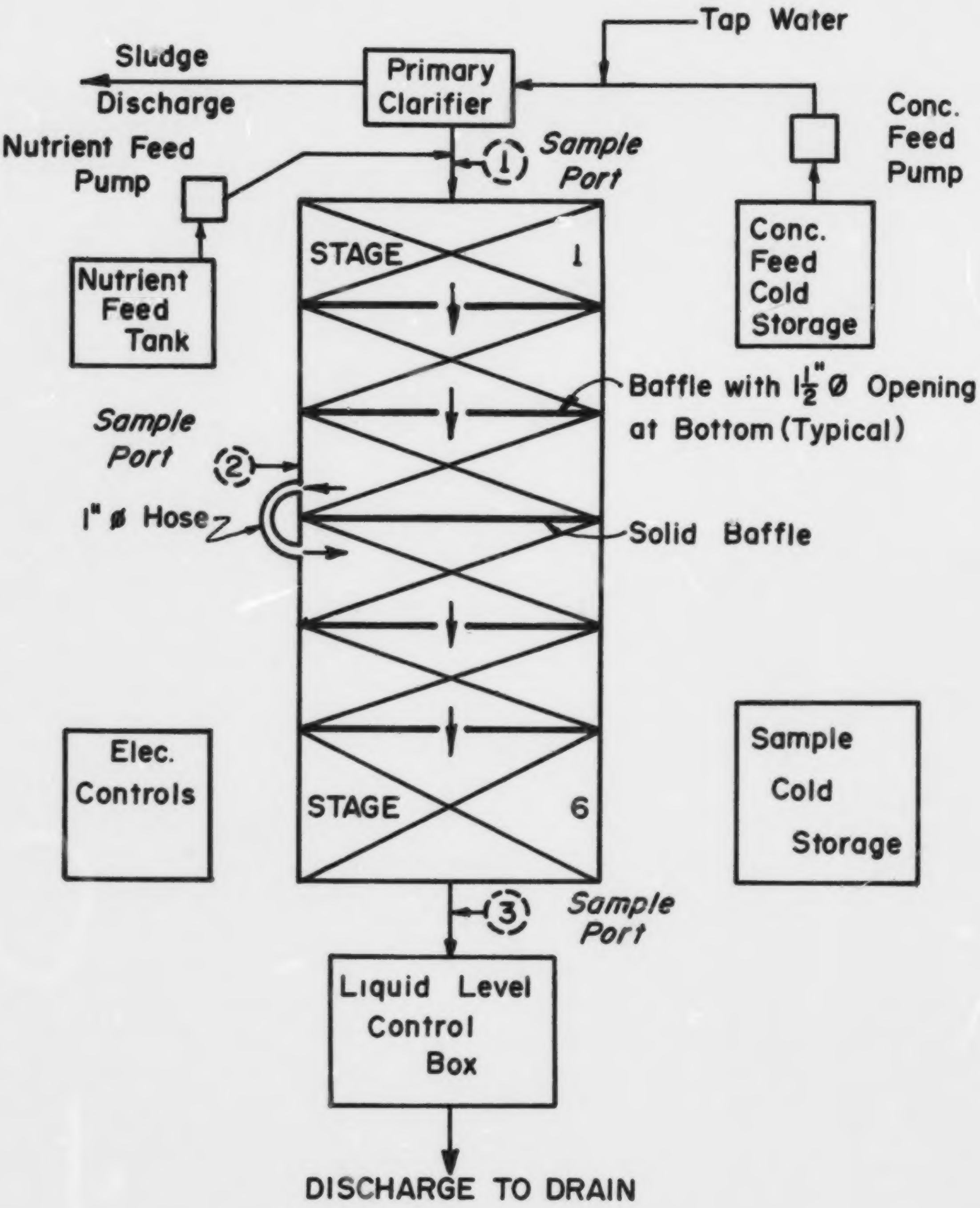


FIGURE 1. RBC PILOT PLANT



Tap Water
Sludge
Discharge
Primary Clarifier
Conc. Feed Pump
Nutrient Feed Pump
① Sample Port
Nutrient Feed Tank
Conc. Feed Cold Storage
STAGE 1
Baffle with 1½" Ø Opening at Bottom (Typical)
Sample Port
②
1" Ø Hose
Solid Baffle
Elec. Controls
STAGE 6
Sample Cold Storage
③ Sample Port
Liquid Level Control Box
DISCHARGE TO DRAIN

FIGURE 2. TREATMENT PLANT FLOW DIAGRAM

Microbiological examinations of the disc slime and mixed liquor were kept general in nature. Daily notes were made of slime morphology. Microscopic slides were examined periodically for relative quantities of broad groups of microorganisms in the mixed liquor and disc slime. Photos were taken of the RBC and microscopic slides at various times to record general changes in relation to loading rates.

Influent and effluent samples were taken as either grab or composite with the composite samples collected either automatically by gravity sampler or on a periodic basis by hand over 18 to 24 hours.

Samples of influent usually were taken every day, Monday through Friday, and effluent samples were collected on Tuesday, Wednesday, and Friday.

Effluent samples were taken from the sixth stage mixed liquor. Then, the samples were placed in graduated cylinders and allowed to settle for 3 hours. Supernatant samples were collected after 1 hour and 3 hours of settling. Sludge was collected only after 3 hours settling.

Table 1 lists the analyses performed.

Table 1. Influent and Effluent Analyses

Influent	Effluent (1 hr settling)	Effluent (3 hr settling)
pH		pH
T-Alk		T-Alk
COD	COD	COD
COD(S)		COD(S)
BOD		BOD
BOD(S)		BOD(S)
TOC		TOC
SOC		SOC
SS	SS	SS
VSS		VSS
TKN		TKN
NH_3-N		NH_3-N
Total-P		Total-P

(S) = soluble (filtrate from 0.45 μ membrane filter)

Mixed liquor samples from the third stage were settled in a graduated cylinder, and the supernatant after 3 hours settling was analyzed for turbidity. Settleability tests were run on both third and sixth stage mixed liquors.

Dissolved oxygen was measured in the first and sixth stage mixed liquors with a YSI probe. Temperature was measured in the primary clarifier, mixed liquor, and ambient air. Relative humidity and temperature of the ambient air were recorded automatically on a continuous recorder.

RESULTS

Figure 3 presents the results of the tracer study of hydraulic detention time. At 0.25 gpd/ft^2 and 0.61 gpd/ft^2 the theoretical hydraulic detention time with 1/8 inch slime was calculated to be 17.1 and 6.3 hours, respectively. From Figure 3 the corresponding values are 13.7 and 4.5 hours. No attempt was made to correct detention time for the effect of biological solids in the mixed liquor. The detention time in Figure 3 does not include primary or secondary settling time.

The RBC was started by filling the mixed liquor tank with effluent from a trickling filter at the Corvallis, Oregon, municipal wastewater treatment plant. Batch feed with dilute synthetic potato waste was used initially while effluent was recycled 100 percent to the influent end. When slime began to appear on the discs, a steady feed rate was established and recycle was discontinued.

Table 2 shows the average and range of influent and effluent parameters, influent loading rates, and removal efficiencies.

TOC and SOC were run in addition to COD and BOD, but the results were inconsistent for Runs #1 and #2 due to sample preservation technique. Run #3 produced 80 to 90 percent removal of TOC and SOC. The organic carbon loading rate (lbs/1000 ft^2/day) was about 40 to 45 percent of the COD loading rate in Run #3 on a total and soluble basis.

VSS removal paralleled SS with 95 to 100 percent of the SS being volatile in both influent and effluent.

Table 2 shows values obtained for 3 hour settled samples, but 1 hour settled samples produced equivalent data for COD and SS removal.

Mixed liquor data are summarized in Table 3. The percent solids data refer to 3 hour settled samples. One hour settled samples produced about 20 to 50 percent greater volumes of wet solids during Runs #1 and #2, but during Run #3, one hour and three hour samples yielded about the same volumes of sludge. Sludge flotation during Run #3 even caused 1 hour sludge volumes to be less than 3 hour volumes occasionally.

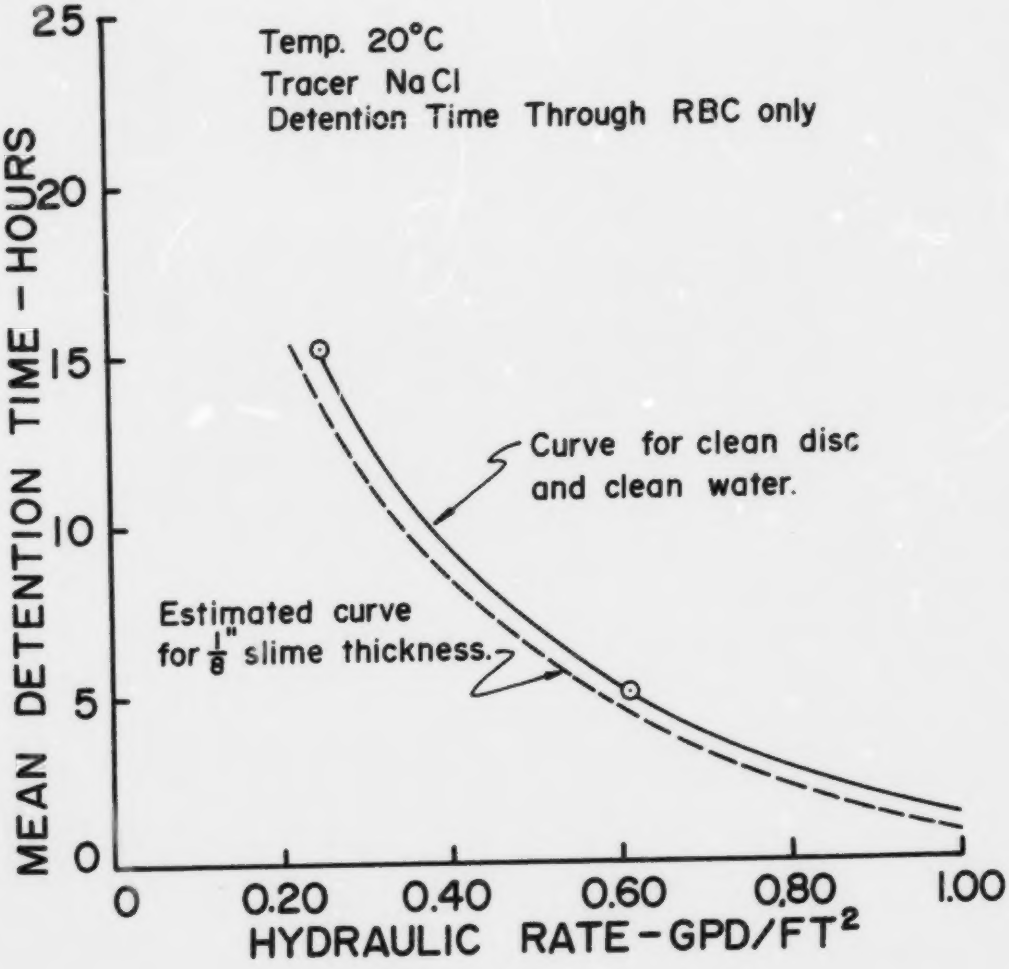


FIGURE 3. MEAN HYDRAULIC DETENTION TIME.

Table 2. Influent and Effluent Data.

Parameter	COD (Total)				COD (Soluble)				% Removal (COD(S)	
	Average		Range		Average		Range			
Station	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Eff	Average	Range
Run No. 1	732	126	671-828	57-218	469	64	323-546	40-136	91	81-95
Run No. 2	2337	332	1710-3100	207-519	1675	142	946-2610	58-205	95	93-96
Run No. 3	2193	313	1860-2510	174-472	1620	196	1420-1840	113-303	91	88-94
Parameter	BOD (Total)				BOD (Soluble)				% Removal BOD(S)	
Run No. 1	508	99	200-635	70-115	297	53	391-560	51-55	92	91-92
Run No. 2	1680	161	1160-2280	125-230	958	60	658-1330	25-110	96	93-99
Run No. 3	1785	198	1520-2190	115-457	1370	74	1260-1480	66-82	95	95-96
Parameter	Inf lbs COD/1000 ft²/day				Inf lbs BOD/1000 ft²/day					
Run No. 1	1.52		1.40-1.73		1.06		0.42-1.33			
Run No. 2	4.86		2.60-6.32		3.35		2.50-4.20			
Run No. 3	10.6		9.2 -12.3		9.0		7.48-10.8			
Parameter	T-Alk				SS				% Removal SS	
Run No. 1	44	46	12-82	24-65	184	70	130-290	40-100	54	17-86
Run No. 2	53	74	14-129	37-103	377	95	240-500	34-180	73	50-93
Run No. 3	143	40	16-407	12-80	536	124	380-680	90-160	76	67-80
Parameter	pH†				T-KN				% Removal T-KN	
Run No. 1	6.8	6.6	6.8-6.8	5.3-7.0	42.9	25.3	35.6-44.9	18.7-33.1	40	
Run No. 2	6.6	6.4	6.3-6.9	5.9-6.8	100.5	58.3	90.5-107	44.4-81.0	42	
Run No. 3	6.5	5.6	6.0-6.6	5.1-6.1	137	76.0	133.0-140	76.0- --	42	
Parameter	NH_3-N				Total-P				% Removal Total-P	
Run No. 1	30.0	2.7	28.9-31.0	1.4-5.0	45.3	36.6	44.0-47.0	28.0-46.0	19	
Run No. 2	70.9	23.1	63.0-81.0	5.4-48.0	103.7	99.6	91.0-116	79.8-110	8	
Run No. 3	77.5	41.6	73.0-82.0	---	121.5	110.0	118-125	110- --	11	
Parameter	BOD/COD				(Average) Inf COD:N (Range)				Inf COD:P	
					Average			Range	Average	Range
Run No. 1	0.71	0.80	0.29-0.94	0.71-0.89	17.4:1			16:1-19.7:1	16.1:1	16:1-17.6:1
Run No. 2	0.74	0.66	0.67-0.82	0.46-0.75	23.6:1			16.7:1-33.9:1	22.9:1	14.9:1-32:1
Run No. 3	0.78	0.63	0.71-0.86	0.58-0.68	20.5:1			18.2:1-22.8:1	23.5:1	19.4:1-27.5:1

Nutrient addition made before Inf Sampling Station

*Data in mg/l unless otherwise noted. Removals and loadings based on 3-hour settling. Inf 20°C

†Median Value

Run No. 1 - Av. 0.25 gpd/ft² total hydraulic flow
Run No. 2 - Av. 0.25 gpd/ft² total hydraulic flow
Run No. 3 - Av. 0.61 gpd/ft² total hydraulic flow

Table 3. Mixed Liquor Data

RUN NO. 1	First Stage		Sixth Stage	
Parameter	Average	Range	Average	Range
D.O. (mg/l)	4.4	--	7.0	--
Temp. (°C)	16.5	15.2-17.6	14.6	13.3-15.8
pH†	6.8	--	--	--
SS (mg/l)	--	--	523	420-700
Solids*	--	--	48	40-55
RUN NO. 2				
Parameter				
D.O. (mg/l)	1.7	1.3-2.3	5.5	5.3-5.6
Temp. (°C)	15.8	15.2-16.5	14.3	14.2-14.4
pH†	--	--	--	--
SS (mg/l)	--	--	951	380-1160
Solids*	--	--	38	7-63
RUN NO. 3				
Parameter				
D.O. (mg/l)	2.0	1.0-2.5	4.4	2.6-5.0
Temp. (°C)	16.3	15.3-17.5	14.5	12.5-16.5
pH†	--	--	5.7	4.6-5.9
SS (mg/l)	--	--	1237	360-1970
Solids*	--	--	79	66-91

†Median value
*3-hr settling, % volume of sludge in 1000 ml glass cylinder.

Percent solids for third stage mixed liquor averaged about the same (for 1 hour and 3 hour samples) as the sixth stage samples.

Table 4 shows settled sludge data from 3 hour settled samples. One hour settled samples were not taken for sludge analysis other than for percent solids which is the same as the mixed liquor one hour sludge volumes discussed above referring to Table 3.

The percent solids data in Table 4 should not be used as absolute values for scale-up work. These values are intended to show only relative amounts of wet sludge that would require pumping for further treatment.

No attempt was made to show quantity of sludge synthesized because of the need for a much more rigorous sampling program, which was beyond the scope of this study.

Figure 4 presents the COD removal characteristics for the three runs made during this study. The data shown were generated from three hour settled samples with the result being $Y = 0.93 X$.

COD applied is total influent COD and COD removed is total influent COD minus soluble effluent COD.

The linear relationship shown in Figure 4 will undoubtedly discontinue at some higher loading and the percent removal will begin to fall off. The location of this breakpoint was not determined due to termination of the project after three runs.

Figure 5 shows the average effluent concentration of soluble COD during the organic loading rates covered in the study. The data represents 3 hour settled effluent, however, 1 hour settled effluent results were essentially the same.

Figure 6 summarizes the suspended solids of settled effluent samples. The lowest concentration obtained was 40 mg/l which occurred during the lowest loading rate. Data from 1 hour samples closely paralleled those from the 3 hour samples.

An attempt was made to correlate COD removal efficiency and relative numbers of microorganisms in the disc slime and mixed liquor, but the results did not appear to be significant.

Figure 7 shows the typical appearance of the slime on stage 3 and 4 discs. The slime was smoother and somewhat less patchy on stages 1 and 2 and more patchy on stages 5 and 6. Slime color varied from cream to brown from stages 1 to 6.

Table 4. Settled Sludge Data*

Parameter	Run No. 1		Run No. 2		Run No. 3	
	Average	Range	Average	Range	Average	Range
TS (mg/kg)	1480	885-2130	3340	2160-6590	2890	1760-3800
TVS (mg/kg)	1220	679-1840	2680	1660-5550	2280	1260-3180
Solids†	48	40-55	38	7-63	79	66-91
TOC (mg/1)	168	96-239	872	810-1180	790	365-1230
BOD (mg/1)	482	226-650	1370	1240-1600	1310	1140-1470
COD (mg/1)	1210	682-2120	2790	1060-6780	2230	1050-3660
TKN (mg/1)	147	62-203	367	174-560	267	240-294
T-P (mg/1)	60	36-77	165	110-220	162	158-172

*3-hr settling in 1,000 ml glass cylinder
† % Volume of Sludge

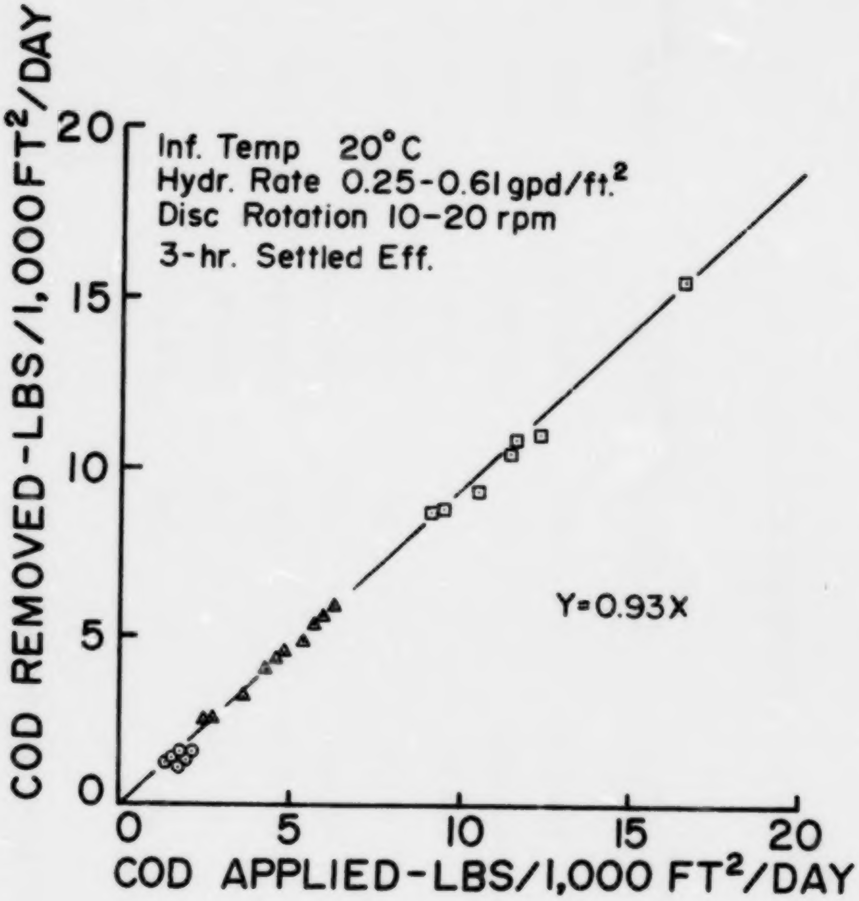


FIGURE 4. REMOVAL CHARACTERISTICS

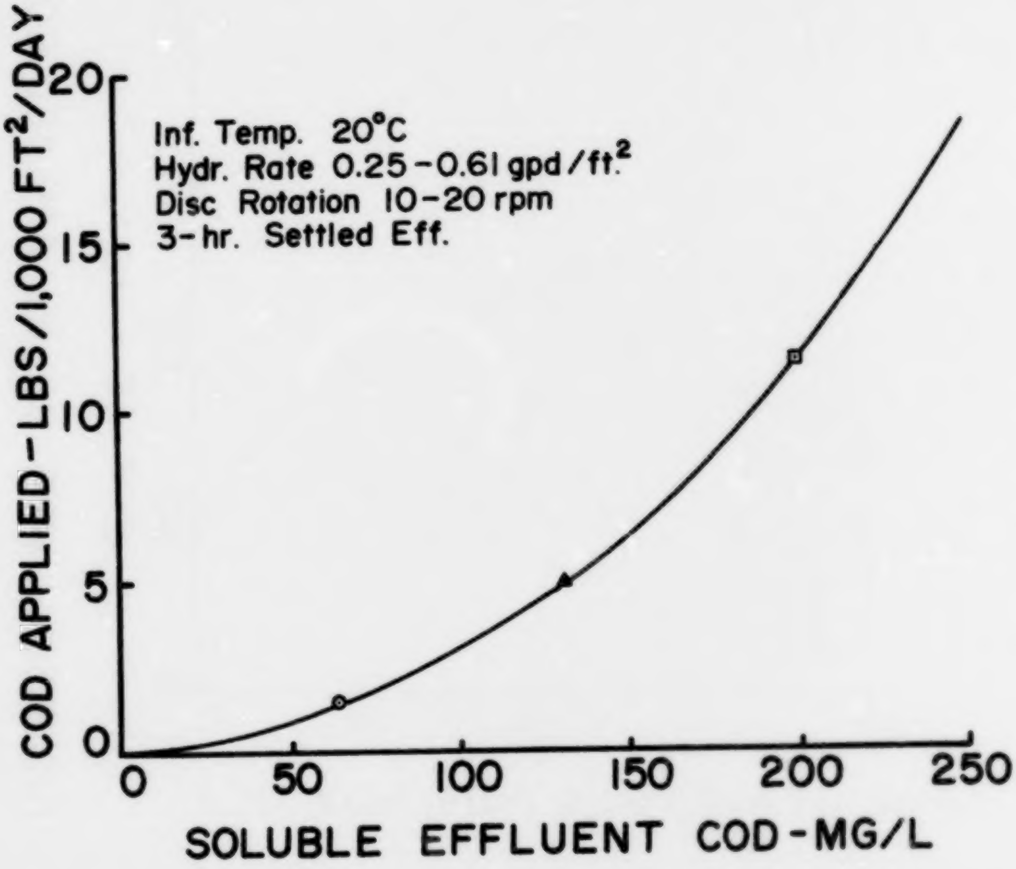


FIGURE 5. SOLUBLE EFF. COD vs APPLIED COD

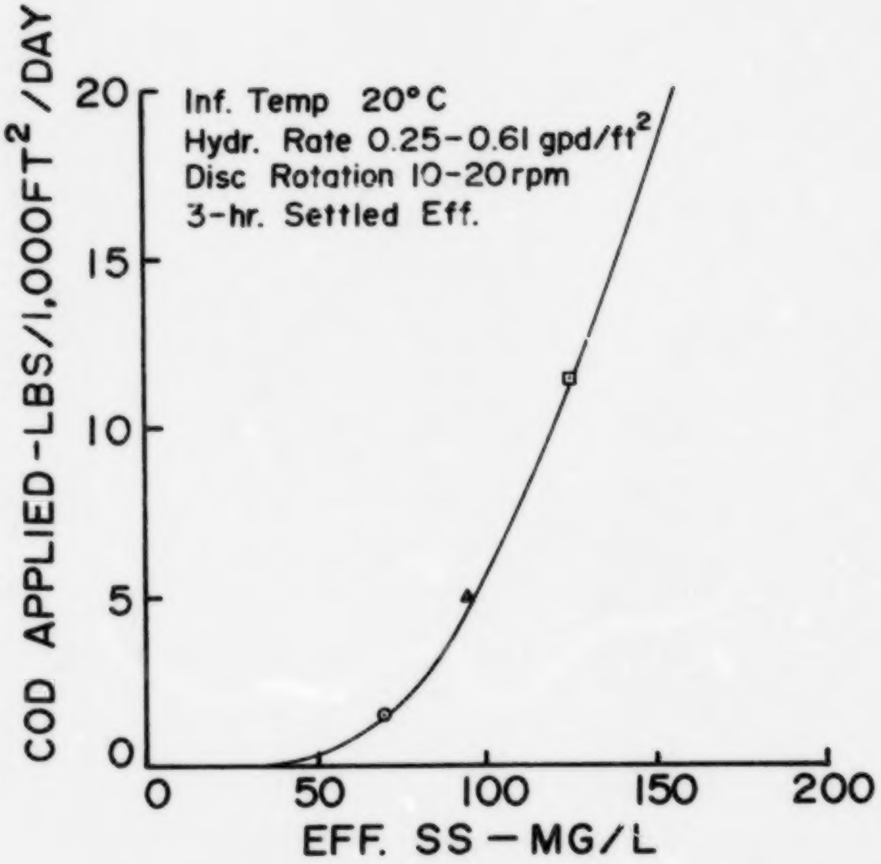
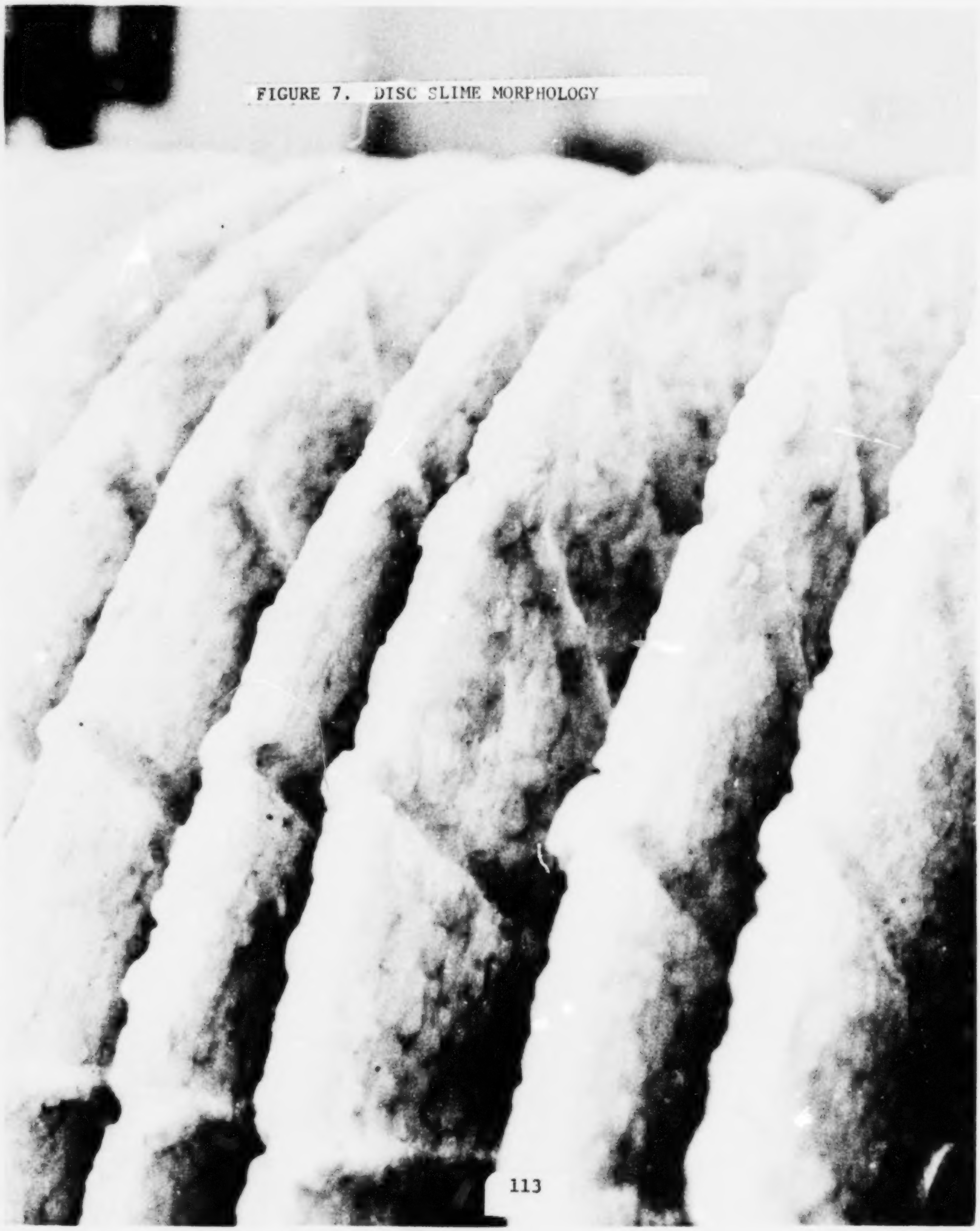


FIGURE 6. EFF. SS vs APPLIED COD

FIGURE 7. DISC SLIME MORPHOLOGY



When the slime sloughed off the discs, it became part of the mixed liquor solids which had the appearance of billowing marabou feathers as presented in Figure 8. The largest mass shown in the photo is about 3x5 inches. Clumps twice that size were observed during the study.

Microscopic examination of mixed liquor and disc slime showed all trophic levels of organisms, including worms and excluding mammals. However, the structural components of the biomass were mostly filamentous bacteria and fungi.

There were no appreciable odors from the RBC unit itself, but during secondary clarification quite offensive odors were evident as a result of anaerobic conditions.

CONCLUSIONS

Within the range of loadings of the study, the RBC proved to be an efficient method of treatment for synthetic potato processing wastewater. However, effluent COD and SS concentrations were higher than those generally considered acceptable for discharge to receiving waters, and additional treatment of the effluent may be required.

All the objectives of the project were not met due primarily to logistic problems. The slime grew "full-scale" size under a "pilot-plant" size project, which caused stoppages in lines and baffle openings and resulted in unsteady state conditions. This problem would have become overwhelming at loading rates beyond those used in the study.

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Autotrol Corp., Milwaukee, Wisconsin

The R. T. French Co., Shelley, Idaho

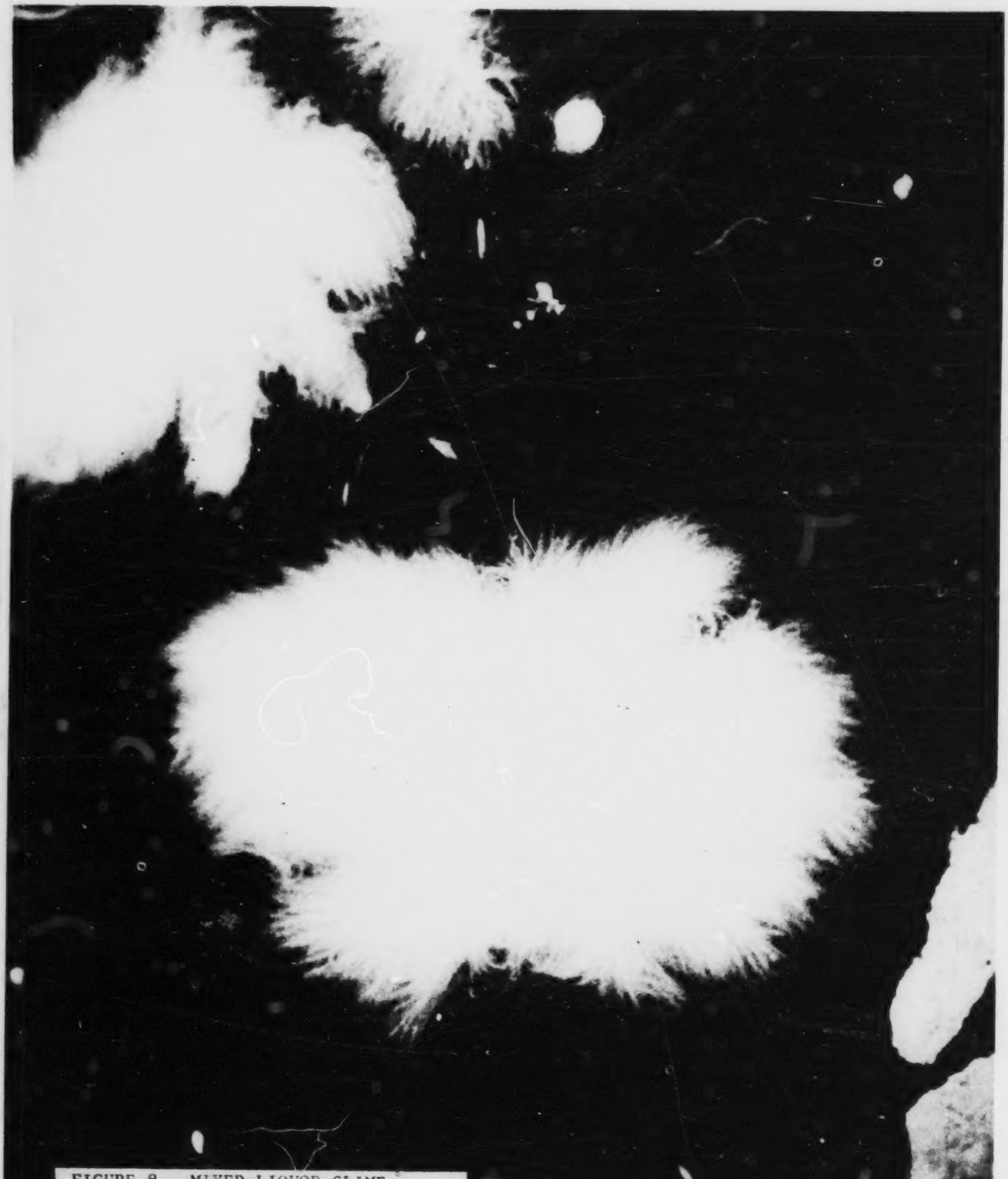

FIGURE 8. MIXED LIQUOR SLIME

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TREATMENT OF SOY WHEY BY MEMBRANE PROCESSES

by

R.L. Goldsmith*, M. M. Stawiarski**, E.T. Wilhelm**,
and H. G. Keeler***

I. INTRODUCTION

The most rapidly growing and commercially attractive area in soybean processing involves the production of protein concentrates and isolates, products containing from 70 to 95% protein. Although manufacture of these products utilizes only a small percentage of the total soybean crop, processing operations generate a large proportion of the total BOD present in a soybean processing plant effluent.

Purification of soy protein from defatted soy flake involves a series of operations (Figure 1). Following extraction with dilute alkali and removal of insoluble solids, proteins are precipitated as a curd by acidification. Different acids are used for edible and industrial grade products. The curd is removed as the desired purified protein product by filtration or centrifugation, and the resultant liquid phase is discarded as waste. This soy whey contains a significant quantity of protein together with carbohydrates (mainly sugars) and some salts. The proteins and the carbohydrates together give the soy whey effluent a variable BOD_5 depending on the operating conditions used in the precipitation step, the time in the process cycle, and the amount of washing performed.

The soy whey proteins are functionally and nutritionally valuable because of their excellent solubility and because they contain a greater proportion of some essential amino acids (such as

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* Abcor, Inc., Cambridge, Massachusetts

** Central Soya/Chemurgy Division, Chicago, Illinois

*** Environmental Protection Agency, Washington, D.C.

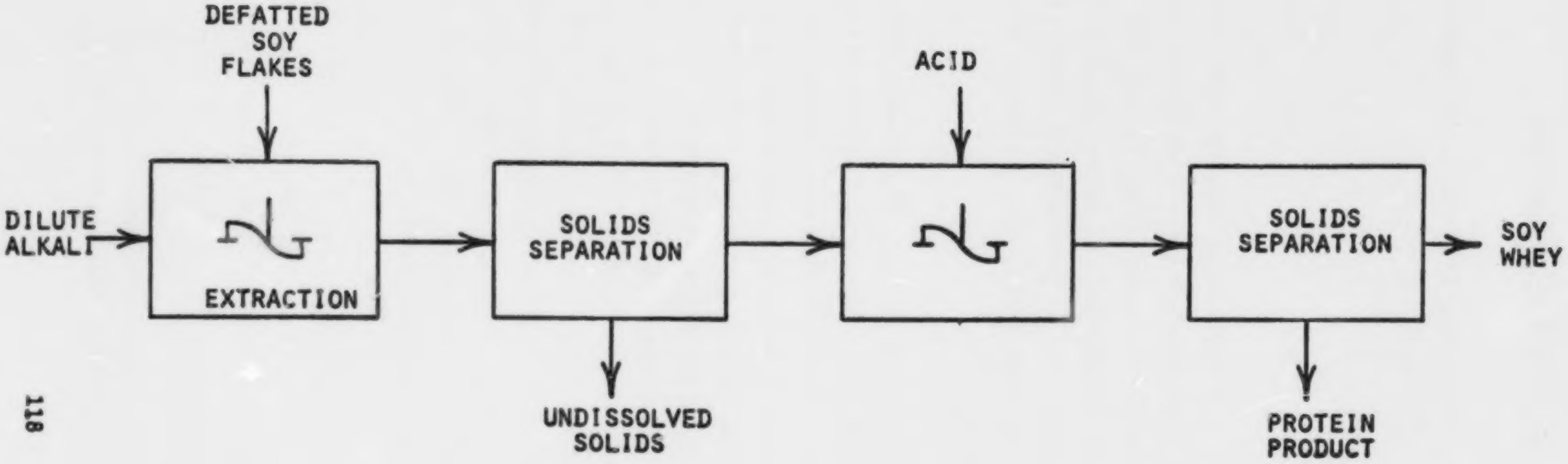
DEFATTED SOY FLAKES
ACID
DILUTE ALKALI
EXTRACTION
SOLIDS SEPARATION
SOLIDS SEPARATION
SOY WHEY
UNDISSOLVED SOLIDS
PROTEIN PRODUCT

FIGURE 1

SOY PROTEIN PROCESS FLOW - SOURCE OF SOY WHEY methionine) than the precipitated fraction. If these proteins can be recovered in undenatured form, they will be at least as valuable as those in the isolate or concentrate now being produced. The loss of the soluble whey proteins and carbohydrates not only results in a water pollution problem, but also represents an economic penalty against the process because otherwise usable materials are being discarded.

Typical composition of soy whey on both a wet and dry basis is given in Table I.

TABLE I

SOY WHEY COMPOSITION

I. Wet Basis	
Total Solids, %	1.5%
Total soluble solids, %	1.4%
Apparent Protein (Nx6.25),%	0.3%
True Protein, %	0.18%
BOD, mg/l	7,700
COD, mg/l	15,200
pH	4.6
II. Dry Basis	
True Protein (Nx6.25), %	12.0
Sugars	45.0
Sucrose, %	24.7
Stachyose, %	16.6
Raffinose, %	3.7
Minerals, %	23.0
Amino Acids, Peptides, other organics, %	20.0
	100.0%

The nature of proteins and sugars from both the edible and industrial protein processes are quite similar and after purification and recovery they should be valuable as process byproducts. In addition, treatment of soy whey by membrane processes, as detailed below, will substantially eliminate the water pollution problem since BOD contaminates will be removed from the final effluent.

Figure 2 shows a simplified flow schematic for the two-step membrane process for soy whey treatment. Operation is almost identical to that used commercially for the treatment of cheese wheys (1,2). In the present case soy whey, with or without filtration for fines removal, is introduced into a low pressure ultrafiltration unit (UF) (step 1). In this operation, whey is concentrated 20 to 40-fold by volume. The ultrafiltration membranes retain only the whey proteins. Thus, it is possible to obtain a protein concentrate with a higher proportion of proteins in the dissolved solids, since sugars, non-protein nitrogen, minerals and other solutes pass through the membrane. Operation is typically in the pressure range of 10 to 100 psi, and at temperatures of 100 to 130°F. The true protein content of raw whey can be increased from an initial value of about 0.2% up to levels exceeding 8% in this step Simultaneously, the proportion of protein in the whey solids can be increased from approximately 12% to 80% in a one-step concentration (that is, without redilution with water and reconcentration).

The permeate (ultrafiltrate) from the UF unit is introduced into a second membrane step. In a reverse osmosis (RO) operation, this stream is concentrated from approximately 1.0% solids to 10% solids or more. Typical operating pressures are 500 to 1500 psi; and temperatures, 70 to 100°F. The membrane in the

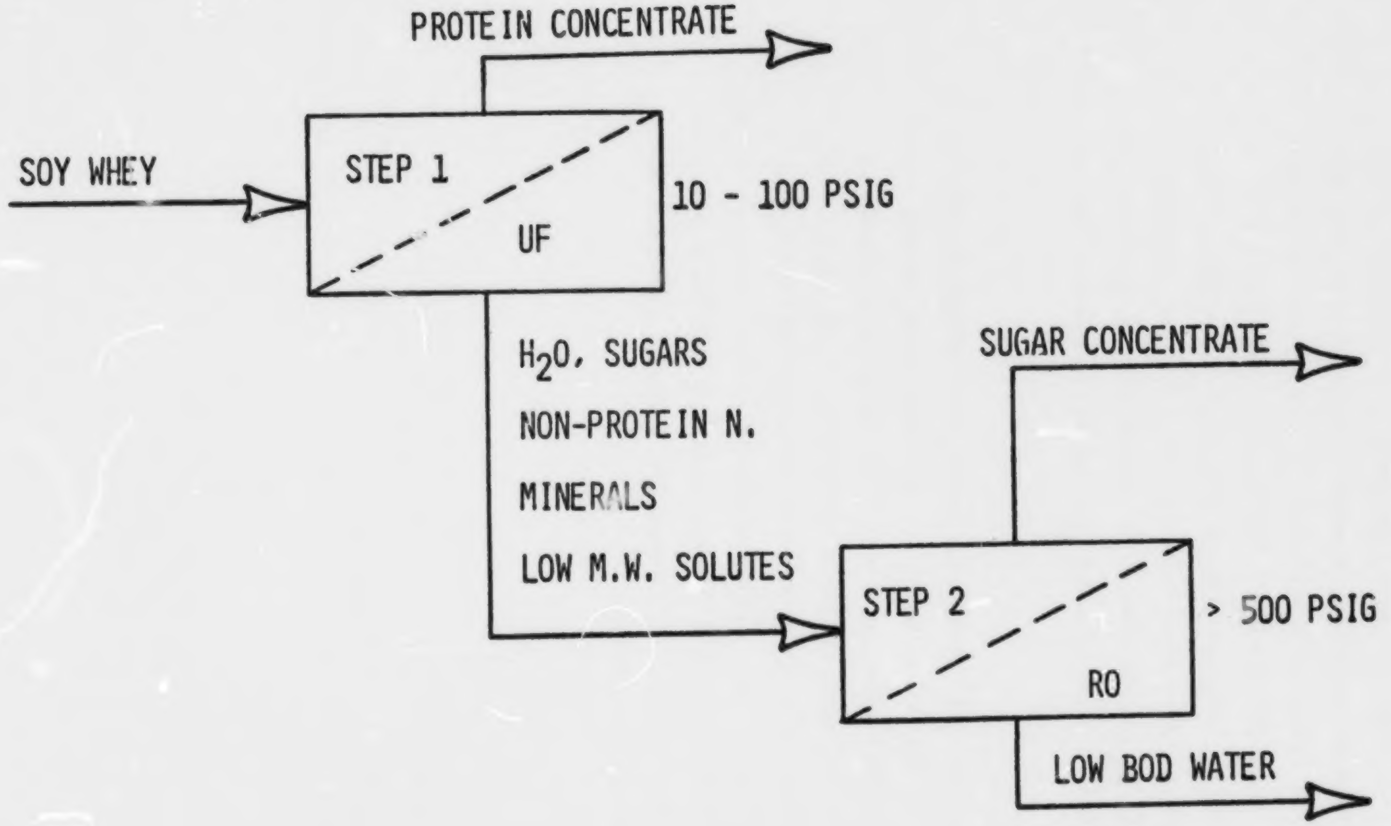
PROTEIN CONCENTRATE
SOY WHEY
STEP 1
UF
10 - 100 PSIG
H_2O, SUGARS
NON-PROTEIN N.
MINERALS
LOW M.W. SOLUTES
SUGAR CONCENTRATE
STEP 2
RO
> 500 PSIG
LOW BOD WATER

FIGURE 2

MEMBRANE PROCESS FOR SOY WHEY TREATMENT - FLOW SCHEMATIC

RO section is chosen to retain as great a proportion of the organic solutes as possible, thereby resulting in a low BOD permeate. The final effluent from the RO section can either be reused within the plant or discharged. Depending on pollution control regulations, a membrane with moderate salt rejection can be used in the RO section to permit partial desalting of the concentrate. In general, from the point of view of pollution control, this option will probably not be exercised.

The membrane test data presented below were obtained under a grant from the Office of Research and Monitoring of the Environmental Protection Agency to the Chemurgy Division of Central Soya, Chicago, Illinois, (Grant No. 12060 FUR). The preliminary data were obtained with tubular membrane units installed at Abcor, Inc. More recently a pilot plant has been operated at Central Soya's Chicago plant to confirm laboratory data, and pilot data are also reported. Pilot operation has been underway since mid-1971.

II. EQUIPMENT AND EXPERIMENTAL PROCEDURES

A. Laboratory Tests

Ultrafiltration and reverse osmosis tests were initially performed at Abcor, Inc., in bench-scale equipment.

The ultrafiltration unit contained 15 ft^2 HFA-180 tubular membranes, and was used to concentrate samples of edible grade whey shipped frozen from Central Soya's Chicago plant. A flow schematic is shown in Figure 3. Whey was charged to a 50 gallon feed tank and heated to 125°F. While processing the whey, its temperature was maintained at this level by passing hot (or cold) water through a coil installed in the tank. Water flow was controlled by a solenoid valve, actuated by a temperature switch installed in the tank.

Whey was recirculated through the tubular membranes with a 2 hp centrifugal pump. The system recirculation rate was measured with a rotameter, and controlled by means of two globe valves. These valves were also effective for controlling the system operating pressure; membrane system inlet and outlet pressures were measured. Fractional water removal per pass through the membranes was very small (typically less than 0.001), and "conversion-per-pass" was negligible. Correspondingly, the system contents were well-mixed.

For batch concentration experiments permeate was withdrawn continuously while the concentrated feed was removed only at the end of the test by draining the system. During batch concentration additional feed was charged to the reservoir to allow processing feed volumes exceeding 50 gallons.

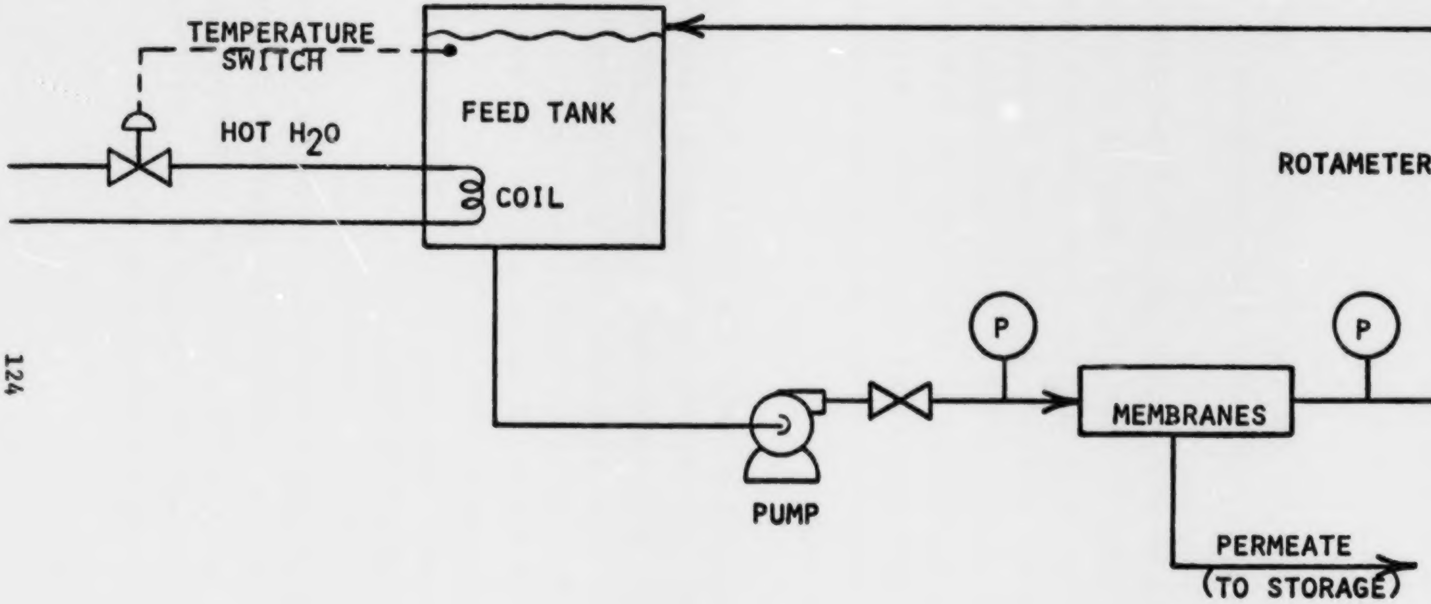
TEMPERATURE SWITCH
FEED TANK
HOT H_2O
COIL
ROTAMETER
P
P
MEMBRANES
PUMP
PERMEATE
(TO STORAGE)

FIGURE 3

LABORATORY TEST SYSTEM FLOW SCHEMATIC

In the same system differential experiments were performed. In these, permeate was returned continuously to the feed tank. This allowed tests to proceed with time-invariant feed concentration and composition.

Batch concentration experiments were employed to determine the dependence of membrane flux and retention on feed concentration. Tests of this nature were generally carried out at a fixed temperature, feed circulation rate and pressure. Differential experiments examined the effects of time, temperature, and pressure on membrane performance.

The reverse osmosis test system was similar in layout to that of the ultrafiltration system. Major differences include the use of a different pump, valves and piping, since operation was at substantially higher pressures. Experiments were of two types, "differential" and "batch concentration". Abcor TM5-14 tubular membrane modules with turbulence promoters were used. Measured salt rejection prior to tests was 96% (80°F, 650 psi, 0.5% NaCl feed). All experiments described below involved processing of permeate collected from batch-concentration ultrafiltration experiments.

B. Pilot Tests

Following completion of laboratory tests, a nominal 1000 gpd pilot unit was built and installed at Central Soya's Chicago facility. Flow schematics are shown in Figures 4 and 5.

Soy whey (125 - 130°F) is piped directly from the protein production plant to a 500 gallon feed surge tank. Whey is drawn from the tank and pumped through a 3-stage ultrafiltration unit. Each stage is recirculated, allowing the maintenance of high

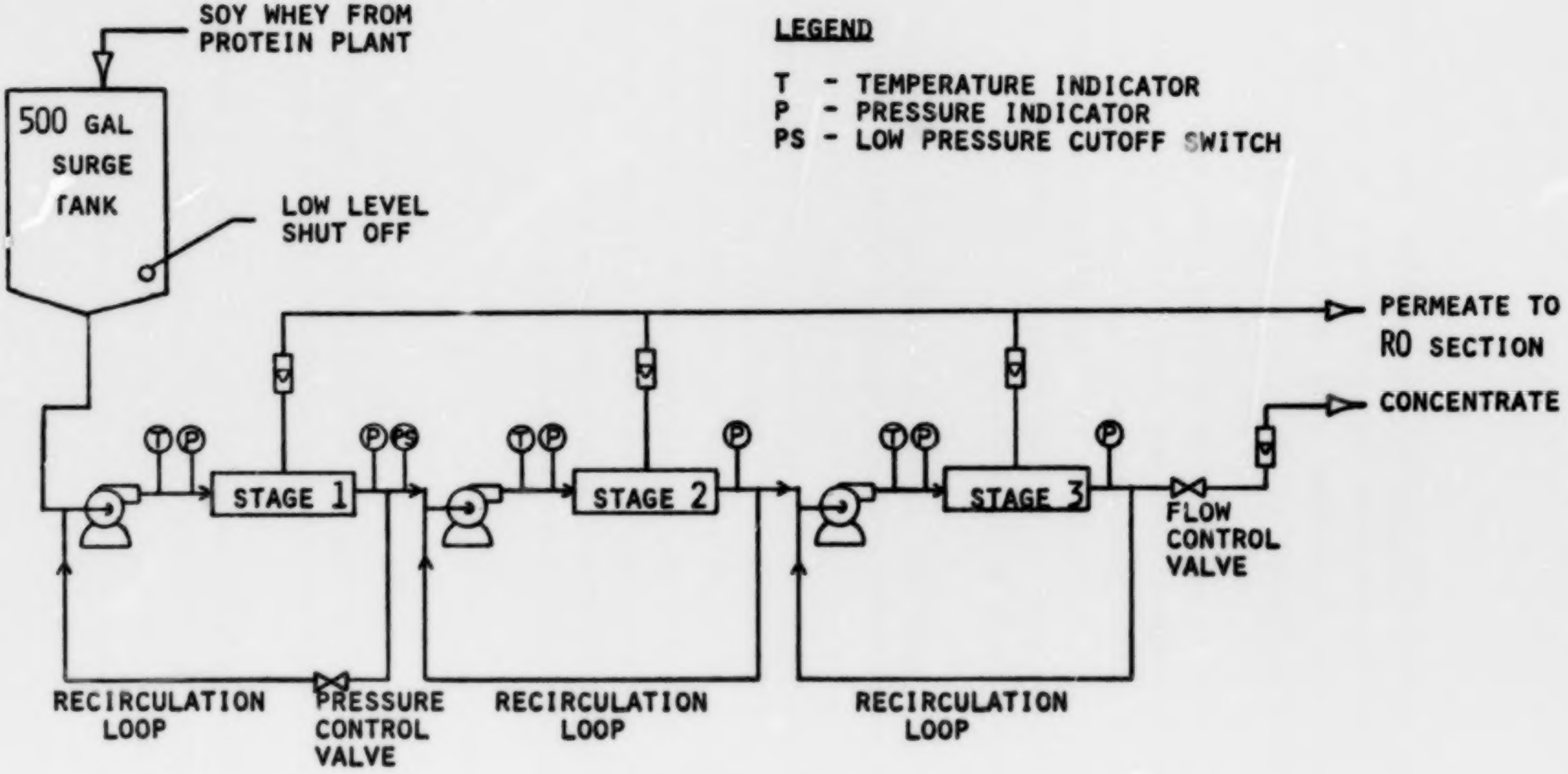
SOY WHEY FROM PROTEIN PLANT
500 GAL SURGE TANK
LOW LEVEL SHUT OFF
LEGEND
T - TEMPERATURE INDICATOR
P - PRESSURE INDICATOR
PS - LOW PRESSURE CUTOFF SWITCH
PERMEATE TO RO SECTION
CONCENTRATE
T
P
STAGE 1
P
PS
T
P
STAGE 2
P
T
P
STAGE 3
P
FLOW CONTROL VALVE
RECIRCULATION LOOP
PRESSURE CONTROL VALVE
RECIRCULATION LOOP
RECIRCULATION LOOP

FIGURE 4

ULTRAFILTRATION SECTION

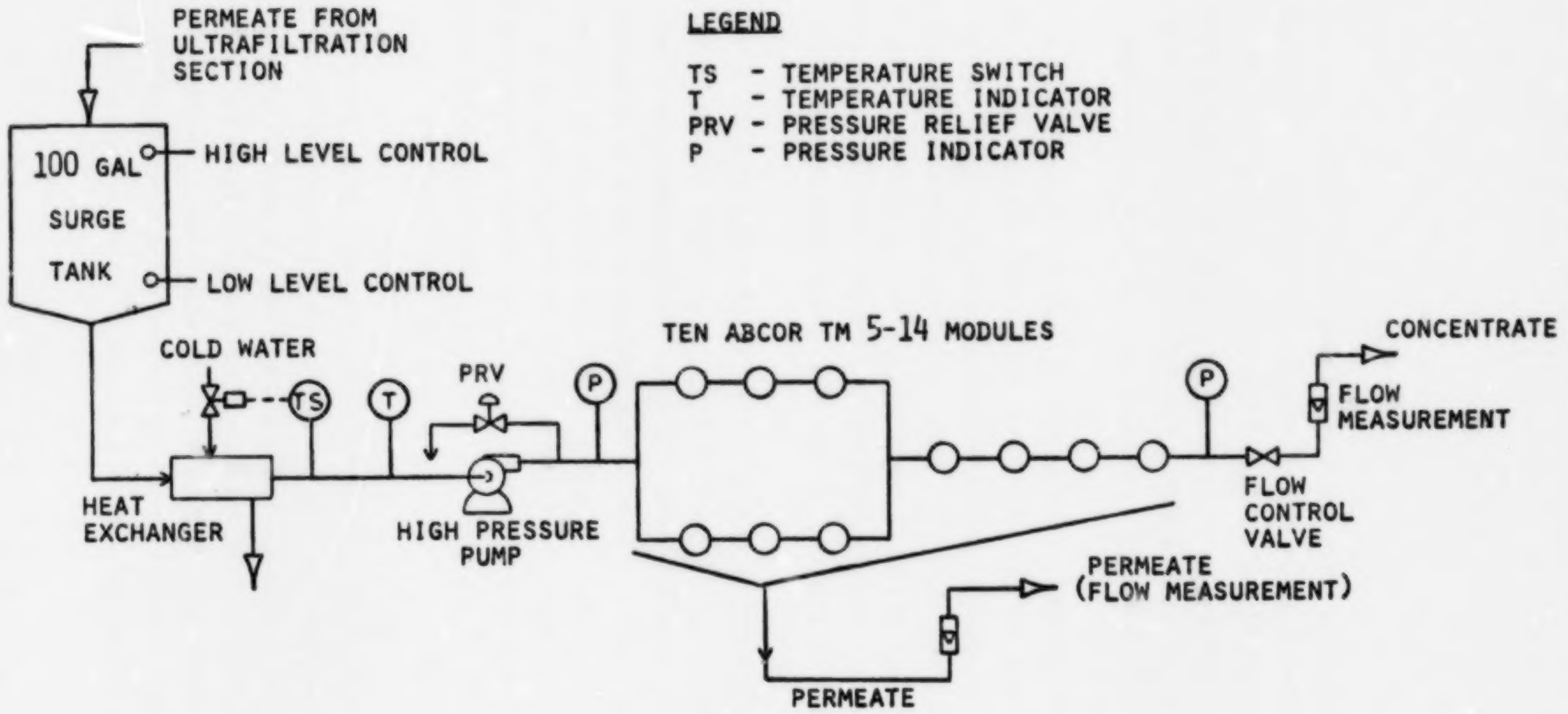
PERMEATE FROM ULTRAFILTRATION SECTION
LEGEND
TS - TEMPERATURE SWITCH
T - TEMPERATURE INDICATOR
PRV - PRESSURE RELIEF VALVE
P - PRESSURE INDICATOR
100 GAL SURGE TANK
HIGH LEVEL CONTROL
LOW LEVEL CONTROL
COLD WATER
TS
T
PRV
P
TEN ABCOR TM 5-14 MODULES
P
CONCENTRATE
FLOW MEASUREMENT
HEAT EXCHANGER
HIGH PRESSURE PUMP
FLOW CONTROL VALVE
PERMEATE (FLOW MEASUREMENT)
PERMEATE

FIGURE 5

REVERSE OSMOSIS SECTION

feed velocity through the tubular membranes, but still enabling operation to proceed with high fractional water removal, or high "conversion". The system can be operated on a once-through basis, with concentrate removed continuously from stage 3, or in a batch mode by allowing a high "bleed" flow from stage 3 to be recycled to the feed surge tank.

An Abcor UF-22S pilot plant is used for each stage. Each unit, containing 22 ft^2 membrane area, is fitted with a calibrated, variable speed, positive-displacement pump to vary, control and measure recirculation rate. Other monitors and instruments measure and control temperature and pressure. The units are fitted with safety devices (conductivity switch, pressure switch, temperature switch) to permit unattended operation.

The permeates from the three stages are fed to a 100 gallon interstage surge tank (Figure 5). Feed to the reverse osmosis system is cooled from the ultrafiltration operating temperature to below $100^{\circ}F$. Due to mechanical strength considerations, the reverse osmosis equipment must be operated at temperatures below this level. Temperature is controlled by an in-line temperature switch (TS), which activates cooling water flow to a heat exchanger. The actual temperature is measured and transmitted to a meter on the control panel.

A high-pressure, positive displacement pump introduces the feed into a series of Abcor TM 5-14 modules equipped with turbulence promoters. Six to ten modules can be tested at one time. Operation is "once-through". A pressure relief valve on the pump outlet controls membrane inlet pressure. Inlet and outlet pressures and the total permeate flow are measured. Downstream flow is measured,and controlled with a flow control valve.

A photograph of the pilot system on site is shown in Figure 6.

Other membrane modules manufactured by Westinghouse, DeDansk Sukkerfabrikker, and Gulf Environmental Systems are also under evaluation. Results reported here were obtained with the Abcor system.

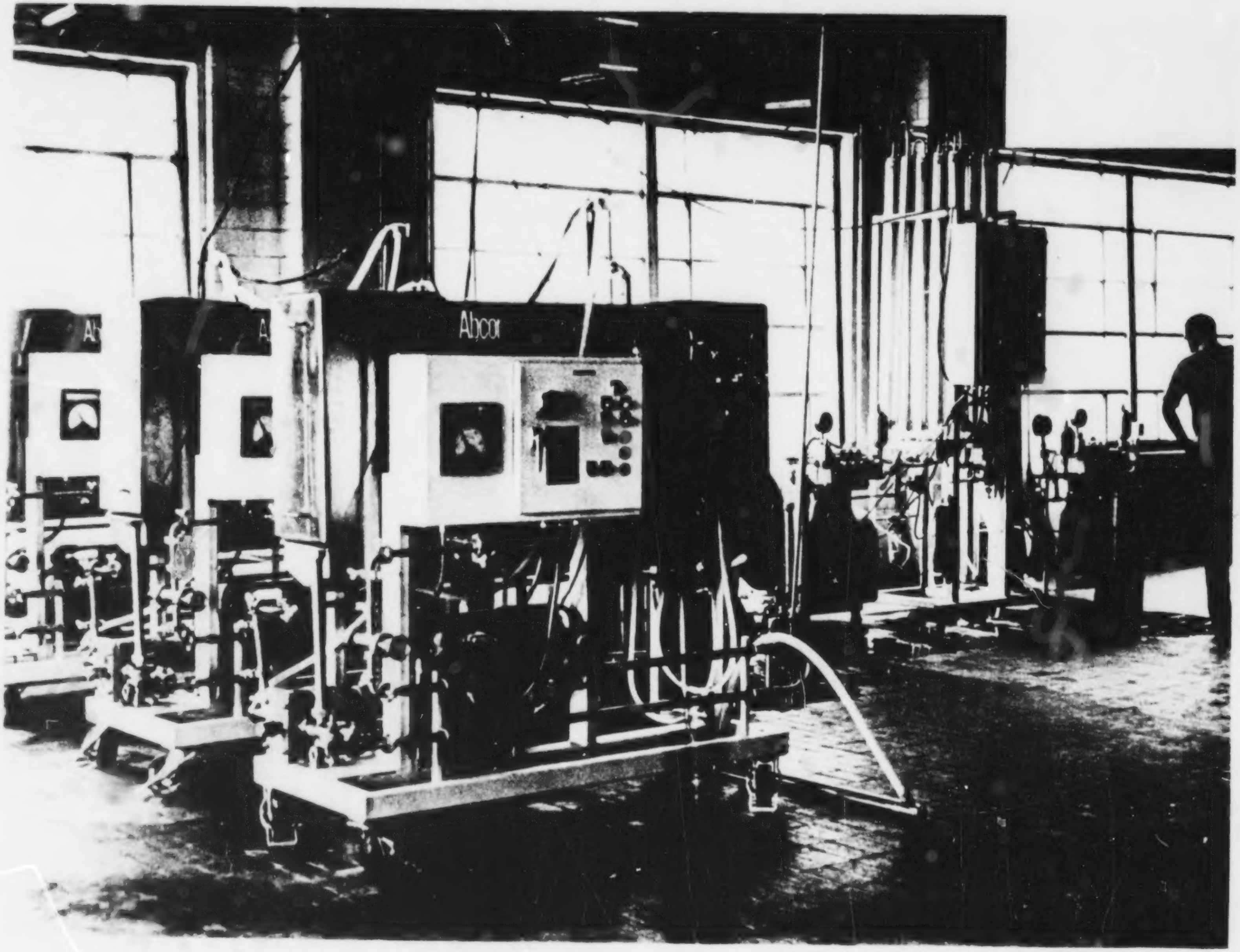

FIGURE 6 PHOTOGRAPH OF PILOT PLANT INSTALLATION

III. ULTRAFILTRATION DATA

A. Dependence of Flux on Time

Membrane fouling has been encountered in both laboratory and pilot tests, as evidenced in flux decay with time. Figure 7 shows data for flux decline over a 24 hour period. These data are for differential operation; that is, feed whey solids and protein contents are essentially unchanged.

In properly cleaned systems, initial flux levels are 25 to 35 gfd (gal/ft^2/day), dropping substantially during the initial 10 hours. With unfiltered whey, laboratory data have exhibited higher values than the pilot unit. This has been true especially when the pilot unit was incompletely cleaned before a test. Whey filtration with a pilot-scale precoat filter resulted in a substantial reduction in flux decline for the pilot plant; the flux level observed was more nearly comparable to laboratory data. Whether or not this will be a preferred process step depends on several factors:

a. The increase in process costs for a filtration step compared with cost reduction for the ultrafiltration step;
b. Loss of recoverable protein in the filtration step; and
c. Relative value of recovered whey protein with and without suspended and colloidal solids removal.

Fouling and the accompanying flux decline are not completely understood, but the following factors are known to be important.

1. Suspended and colloidal materials contain a "foulant" which coats the membrane surface, reducing flux.

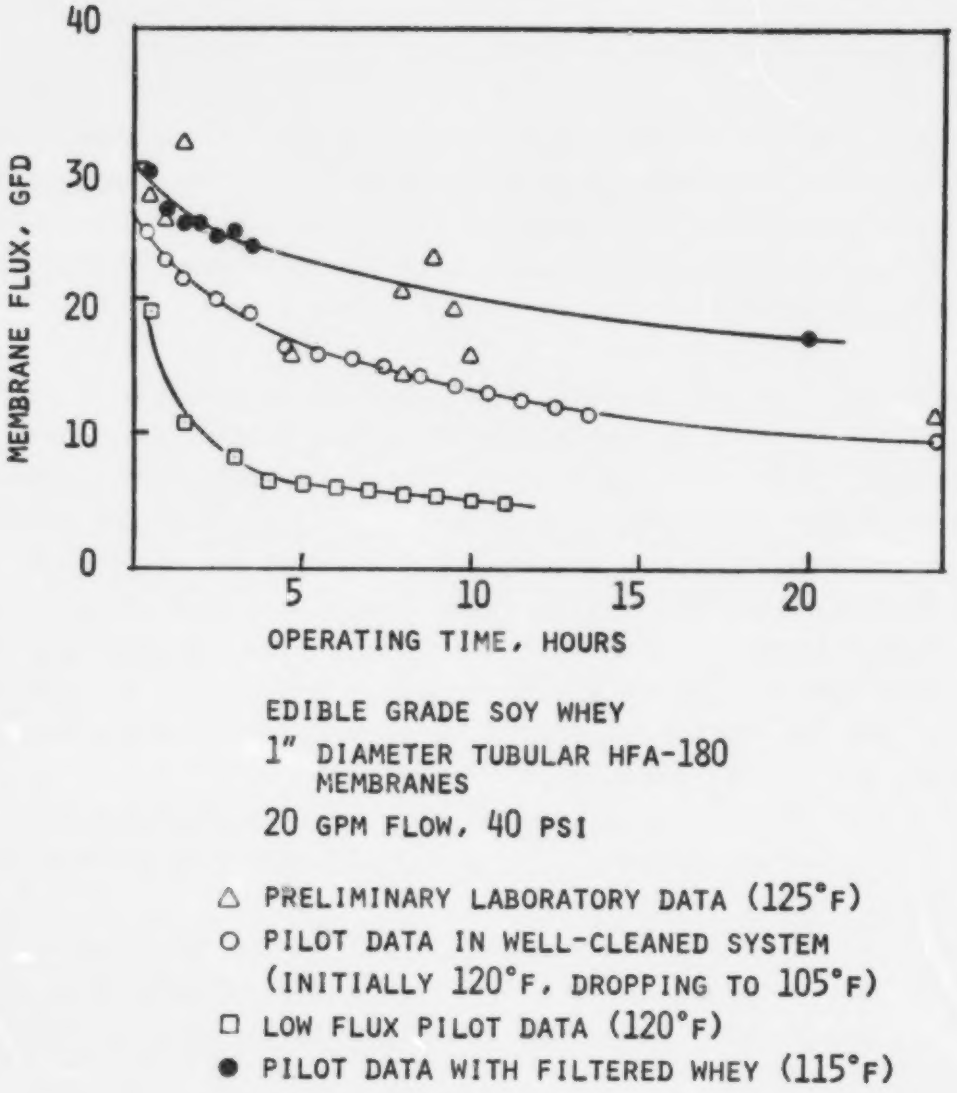

FIGURE 7: ULTRAFILTRATION FLUX AS A FUNCTION OF TIME

Filtration partially removes the foulant and the flux decline problem is relieved substantially. Also, fouling appears to be less severe when a small batch of whey is recirculated within the unit than when fresh whey is continuously fed to the unit. This suggests that the whey contains a material adsorbed by the membrane surface, and that maximum fouling occurs when the highest amount of foulant is processed per unit membrane area.

2. Microbiological growth, accompanied by whey acidification, results in a rapid flux decline. Turbidity develops in the whey under these conditions, as expected, since additional dissolved protein is precipitated. Addition of preservatives, such as hydrogen peroxide, inhibits bacterial growth and acidification, and reduces flux decay.

3. When the membranes are not completely cleaned befor a test, fouling is especially severe.

In general,no correlation is exhibited between fouling and operating temperature, pressure and feed circulation rate.

Reasons for the difference between laboratory data and pilot plant performance are not clearly understood. Changes in processing conditions in the protein plant which occurred between laboratory tests and the initiation of pilot studies are suspect. These may have changed the nature of the whey. There were no apparent differences in membrane properties; replacement of some of the membranes in the pilot unit by ones used in the laboratory did not result in improved performance.

We are currently trying to determine the optimum means of maintaining high flux levels. High, stable fluxes will reduce the membrane area requirement for a full-scale plant and minimize down-time for system cleanup. Both are obviously desirable from the point of view of process costs.

B. Dependence of Flux on Feed Concentration

Flux data for laboratory and pilot plant tests as a function of feed concentration are shown in Figure 8. The laboratory test with raw whey and pilot tests with raw and filtered whey were performed as batch concentrations. Thus, in all three there were high fluxes at low concentrations during the initial part of the test. Operating times for the tests are given in Tables II, III, and IV.

Although time and temperature play important roles, higher fluxes were experienced in the laboratory than in the pilot plant. For all tests, flux declined with feed concentration. Similar flux behavior has been observed in the ultrafiltration of cheese wheys (1,2)

C. Retention Data

Figure 9 shows the dependence of retention* of both protein and total solids on feed concentration. Retentions for both increase with increasing feed concentration, since at higher concentrations a greater proportion of the solutes consist of higher molecular weight materials. Protein retention is always less than 100%

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[*] Retention is defined as: $\frac{C_{feed} - C_{permeate}}{C_{feed}} \times 100$

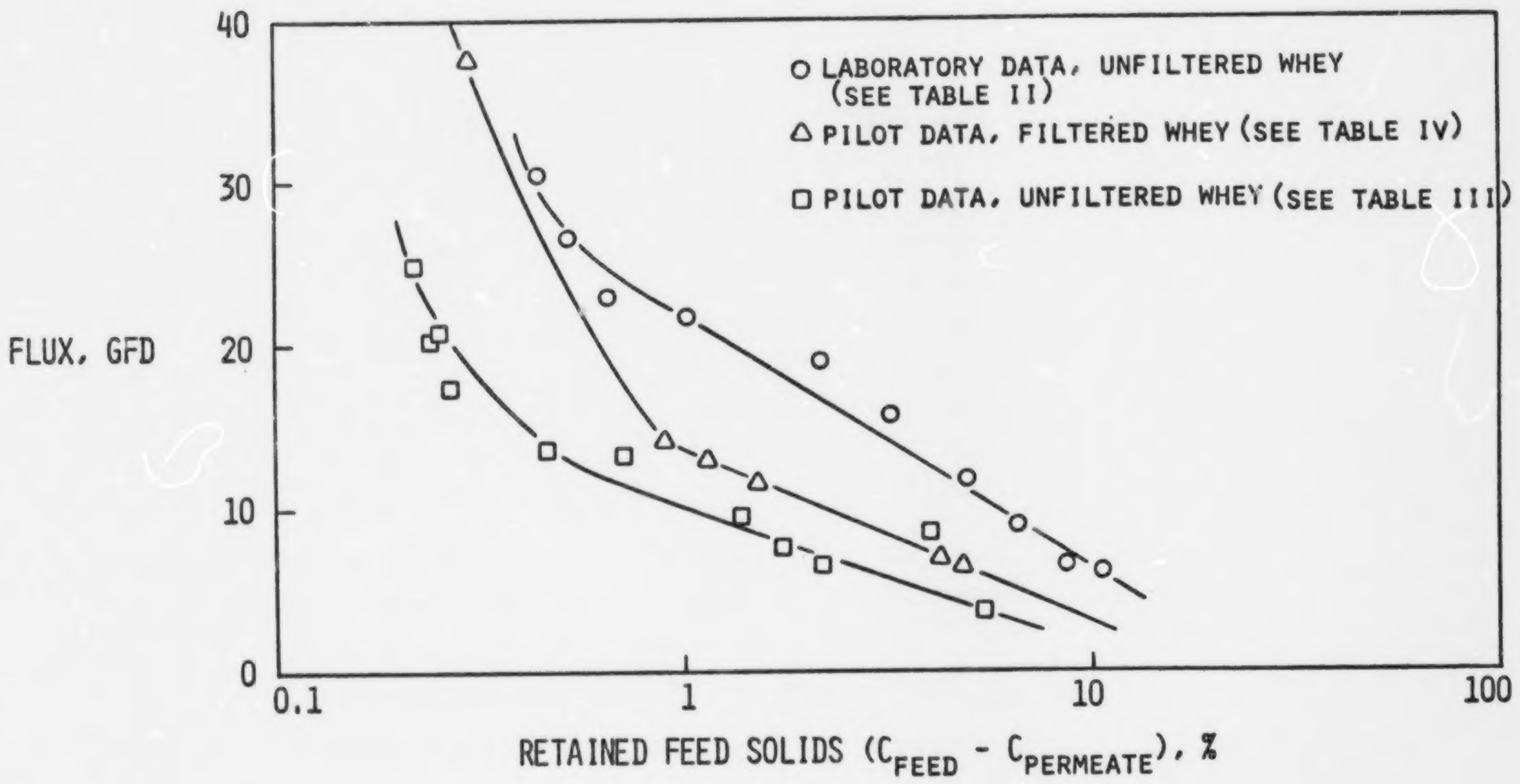

FIGURE 8

DEPENDENCE OF FLUX ON FEED CONCENTRATION

TABLE II

LABORATORY TEST WITH UNFILTERED SOY WHEY

(Operating Conditions: 20 gpm, 40 psig)

Operating Time Hours	Temperature °F	Flux gfd	Feed Solids %	Feed Protein %
0.10	70	31.2	1.30	0.27
0.35	82	26.5	1.38	0.30
2.33	122	23.0	1.63	0.44
6.72	122	21.8	1.99	0.63
9.48	124	19.1	3.25	1.55
10.23	125	15.8	4.39	2.40
10.85	126	11.9	6.04	3.42
11.30	126	9.0	7.86	5.08
11.70	126	6.6	9.94	6.63
11.95	133	6.3	12.03	7.85

TABLE III

PILOT TEST WITH UNFILTERED SOY WHEY
(Operating Conditions: about 20 gpm, 40 psig)

Operating Time Hours	Temperature °F	Flux gfd	Feed Solids %	Feed Protein %
		STAGE 1		
0.5	119	25.1	1.22	0.35
1.0	120	22.9		
1.5	120	21.3		
2.5	119	19.8		
3.5	118	19.2		
4.5	118	17.4	1.27	0.37
5.5	115	16.4		
8.5	110	13.0		
13.5	105	11.0		
22.5	90	9.5	2.37	1.15
26.5	104	8.7	4.96	3.39
		STAGE 2		
0.5	115	20.2	1.28	0.35
1.0	121	19.1		
1.5	122	18.0		
2.5	121	16.0		
3.5	120	14.9		
4.5	120	13.6	1.46	0.50
5.5	118	12.8		
8.5	114	11.0		
13.5	108	9.2		
22.5	94	7.6	2.73	1.35
26.5	110	6.5	5.75	3.92
		STAGE 3		
0.5	100	20.7	1.25	0.52
1.0	112	18.5		
1.5	116	18.0		
2.5	116	16.2		
3.5	116	14.7		
4.5	116	13.1	1.72	0.70
5.5	114	12.0		
8.5	109	10.0		
13.5	104	8.5		
22.5	93	6.5	3.15	1.65
26.5	108	3.8	6.39	4.47

TABLE IV

PILOT TEST WITH FILTERED SOY WHEY
(Stage 1 only)

(Operating Conditions: approx. 20 gpm, 35 psig)

Operating Time Hours	Temperature °F	Flux gfd	Feed Solids %	Feed Protein %
0.1	107	37.5	1.30	0.25
1.0	114	28.4		
4.25	114	14.1	1.90	0.72
4.75	114	13.0	2.13	0.90
5.25	114	11.7	2.48	1.22
6.33	114	7.0	5.3	3.3

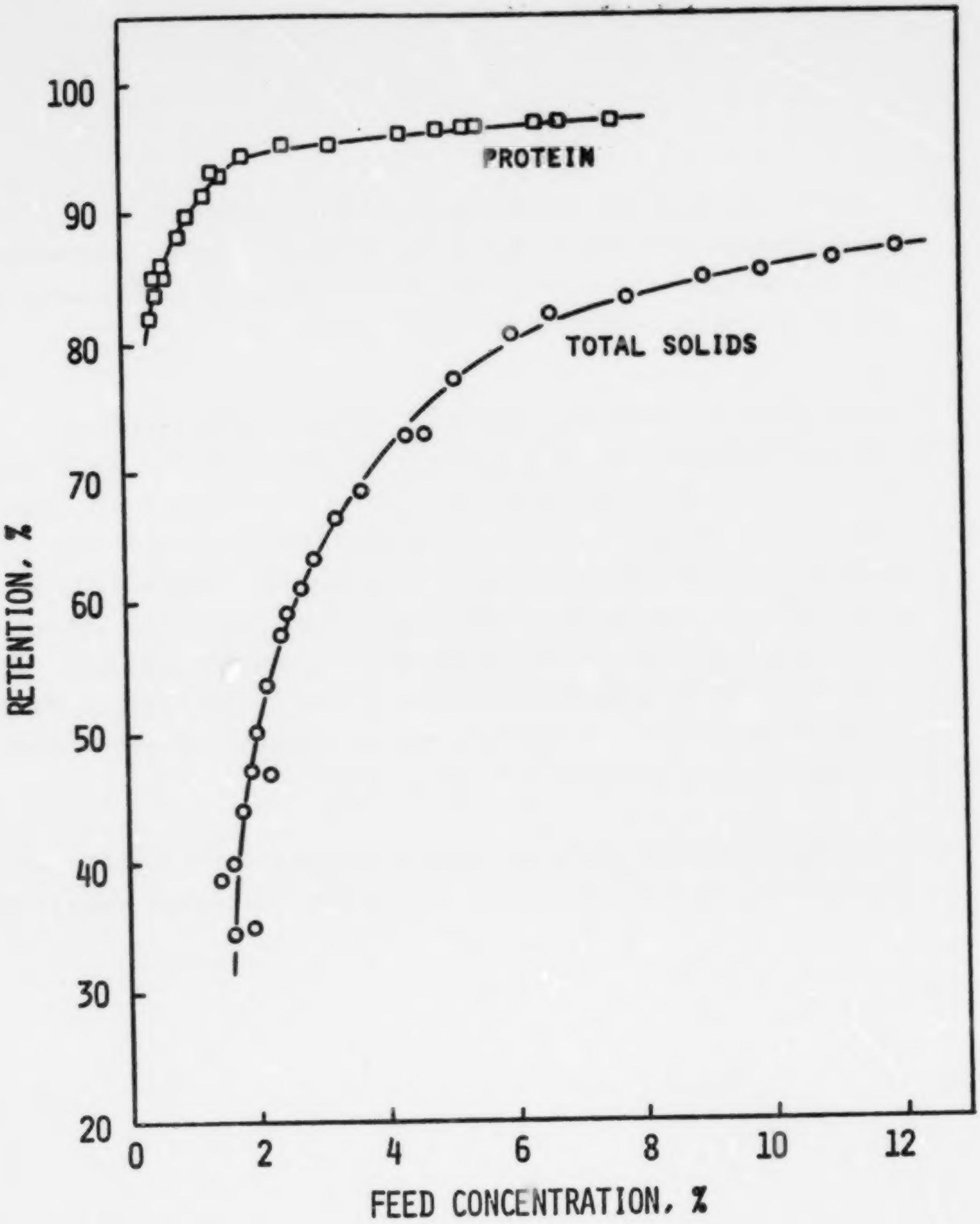

FIGURE 9

LABORATORY ULTRAFILTRATION RETENTION DATA

(EDIBLE GRADE SOY WHEY AS FEED)

because the protein assay is sensitive to lower molecular weight polypeptides and amino acids which pass through the membrane. Gel permeation chromotography experiments have demonstrated that "true" protein retention exceeds 98%.

Since protein retention exceeds total solids retention the protein composition of the feed solids increases with concentration. This is shown by the data of Figure 10, for both laboratory and pilot data. Protein concentration and composition is presented as a function of feed solids in the concentrate. Laboratory and pilot data generally agree, with the exception that pilot experiments produced products with somewhat higher protein contents (~80%). Filtration made little difference, since solids removed by filtration were comprised of protein and non-protein materials.

Figures 11 and 12 show material balances for representative laboratory (unfiltered whey) and pilot (filtered whey) tests.

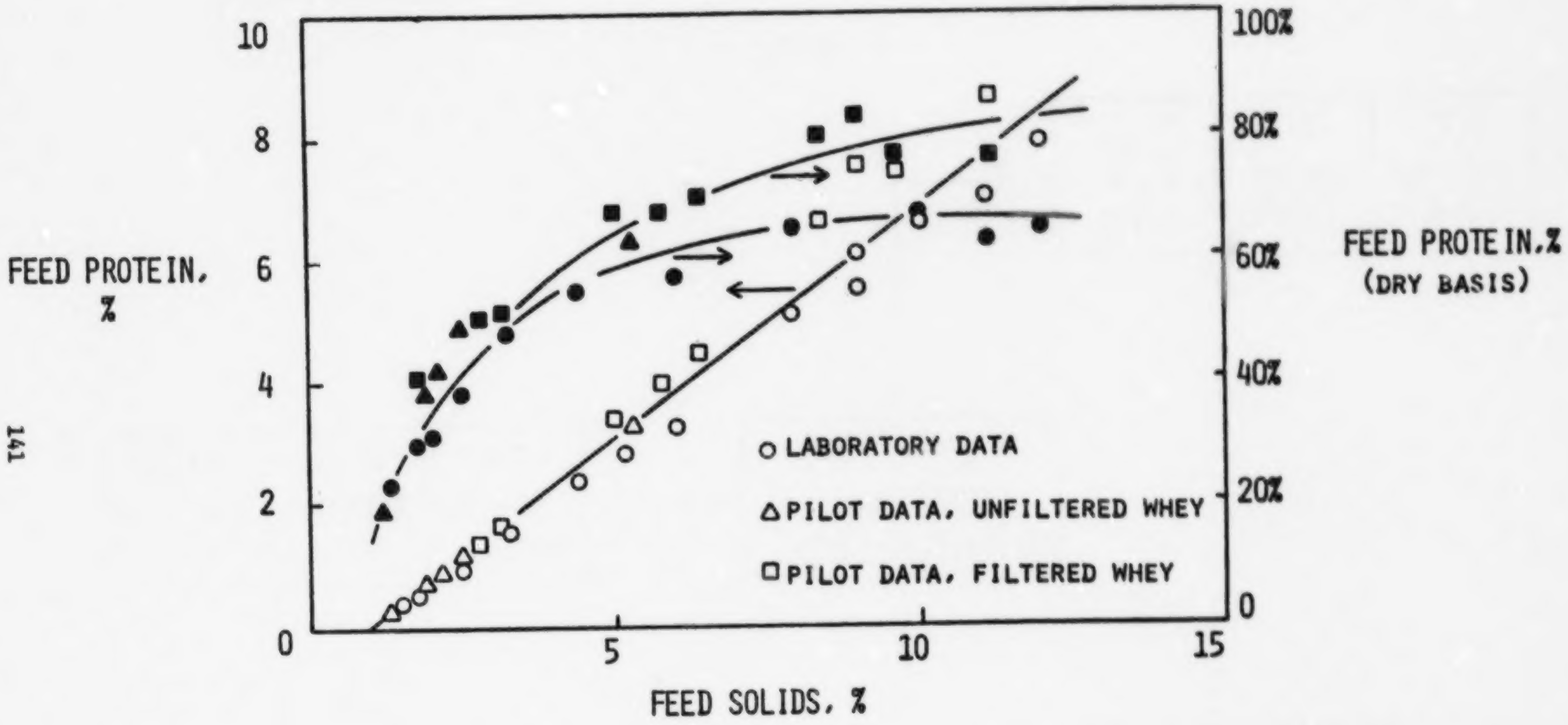

FIGURE 10

COMPOSITION OF PROTEIN CONCENTRATES

(FILLED SYMBOLS ARE COMPOSITION; EMPTY SYMBOLS ARE CONCENTRATION)

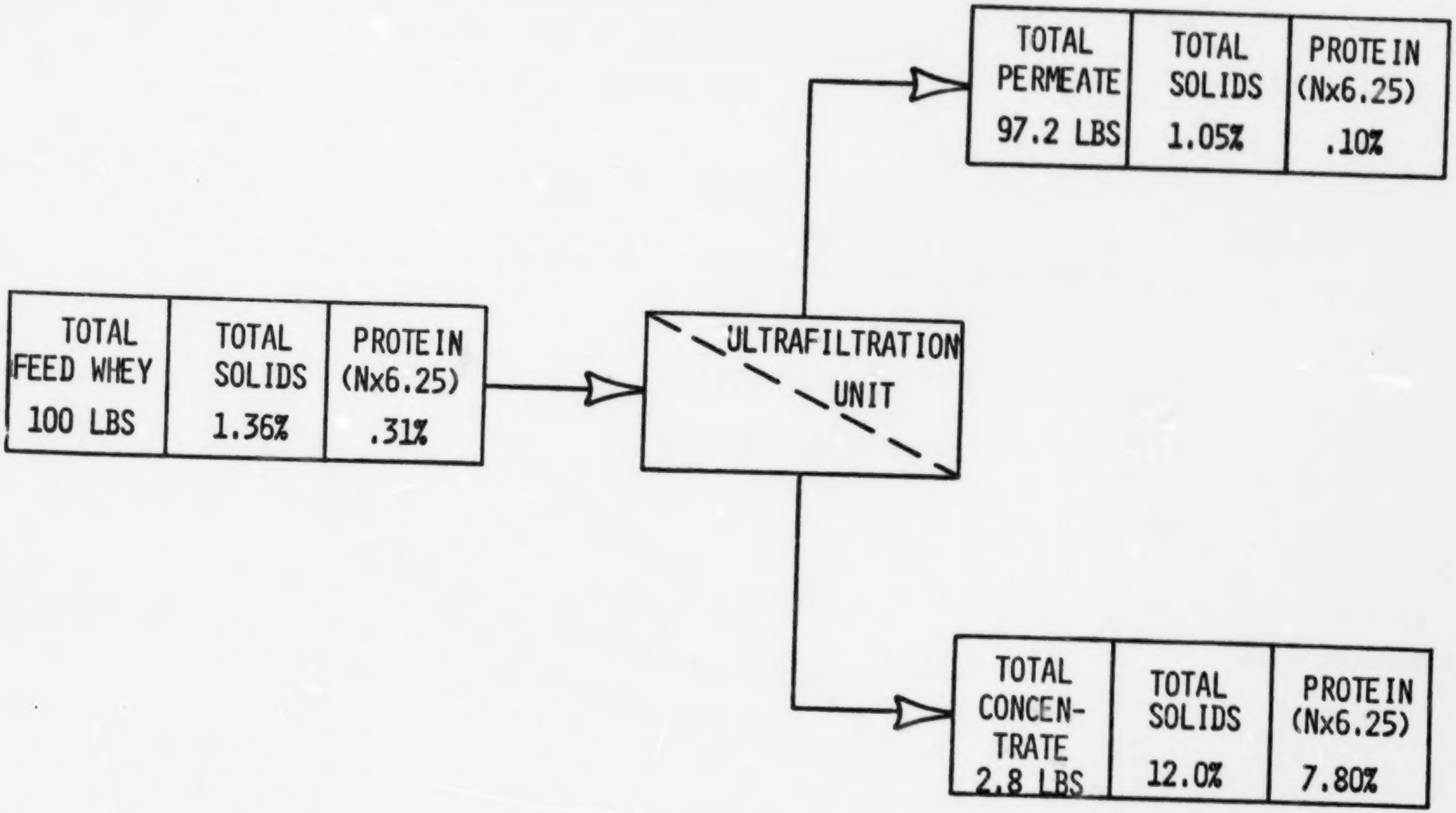
TOTAL FEED WHEY 100 LBS
TOTAL SOLIDS 1.36%
PROTEIN (Nx6.25) .31%
ULTRAFILTRATION UNIT
TOTAL PERMEATE 97.2 LBS
TOTAL SOLIDS 1.05%
PROTEIN (Nx6.25) .10%
TOTAL CONCENTRATE 2.8 LBS
TOTAL SOLIDS 12.0%
PROTEIN (Nx6.25) 7.80%

FIGURE 11

LABORATORY CONCENTRATION OF SOY WHEY BY ULTRAFILTRATION - MATERIAL BALANCE

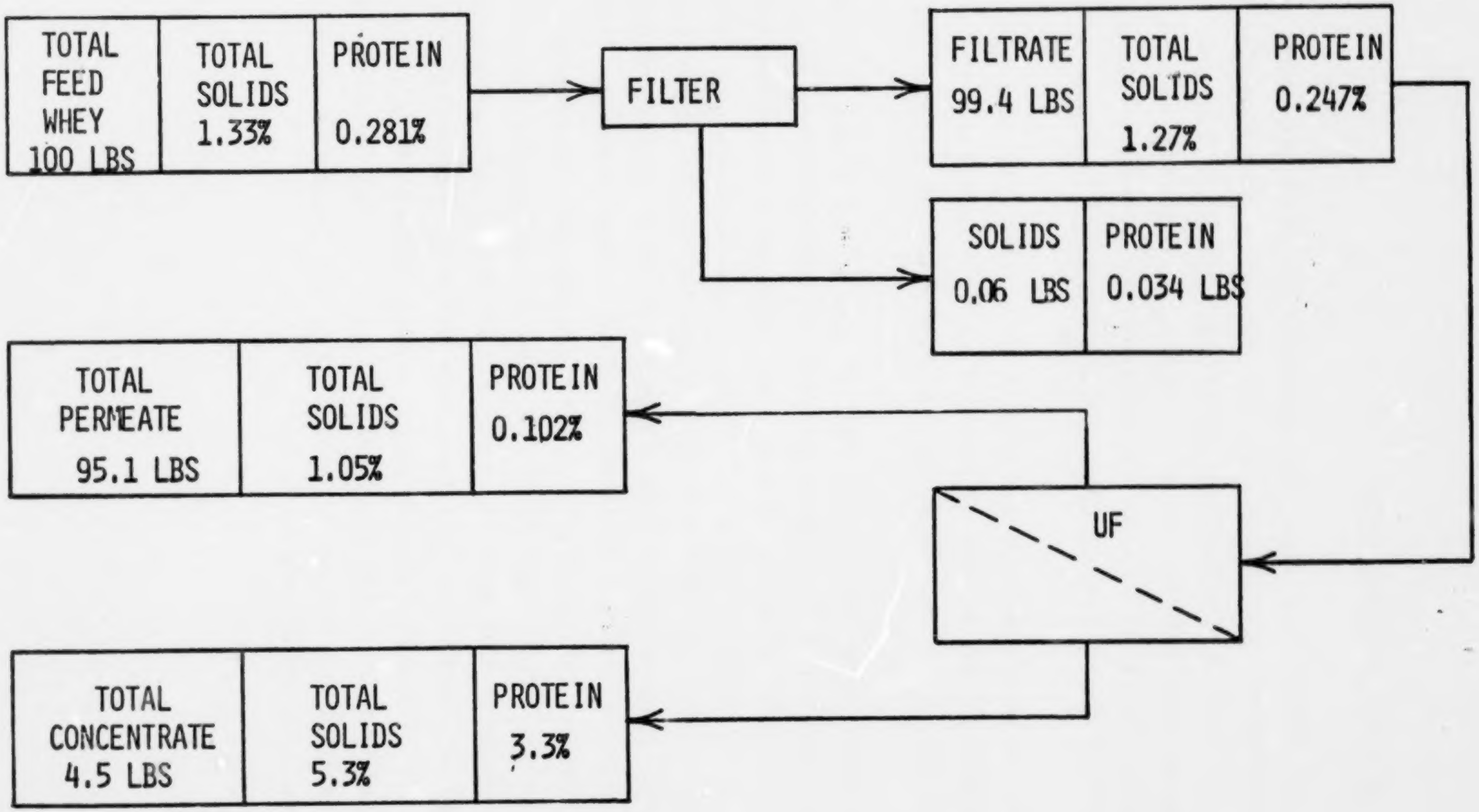
TOTAL FEED WHEY 100 LBS
TOTAL SOLIDS 1.33%
PROTEIN 0.281%
FILTER
FILTRATE 99.4 LBS
TOTAL SOLIDS 1.27%
PROTEIN 0.247%
SOLIDS 0.06 LBS
PROTEIN 0.034 LBS
UF
TOTAL PERMEATE 95.1 LBS
TOTAL SOLIDS 1.05%
PROTEIN 0.102%
TOTAL CONCENTRATE 4.5 LBS
TOTAL SOLIDS 5.3%
PROTEIN 3.3%

FIGURE 12

PILOT PLANT CONCENTRATION OF SOY WHEY BY ULTRAFILTRATION - MATERIAL BALANCE

IV. REVERSE OSMOSIS DATA

Typical laboratory data for concentration of soy whey permeate are presented in Figures 13, 14, and 15. The dependence of flux on feed concentration is shown in Figure 13, and it is apparent that concentrates exceeding 10% solids can be produced at 600 psi. Other experiments at higher pressures have generated concentrates with solids levels exceeding 20%.

Figure 14 shows solids retention observed with the AS-197 membranes. COD or BOD retention is approximately the same, as reflected in the material balance data of Figure 15.

These data have been confirmed in the pilot plant. Tabulated data, covering a six-month period of intermittant operation, are given in Table V. These test data were selected to illustrate several points. First, flux is strongly dependent on the degree of concentration achieved in the once-through system. Flux dropped from 10 gfd for about 1.5-fold concentration to 2.1 gfd for about 15-fold concentration. The flux level, and its decline with increasing conversion, are similar to laboratory data, as seen by reference to Figure 13. Total solids, BOD and COD retentions were good, as demonstrated by comparing the feed and permeate compositions of Table V. Finally, during pilot plant operation there has been no substantial change in flux or rejection efficiency of the reverse osmosis system. Other data, not reported here, further confirm this conclusion.

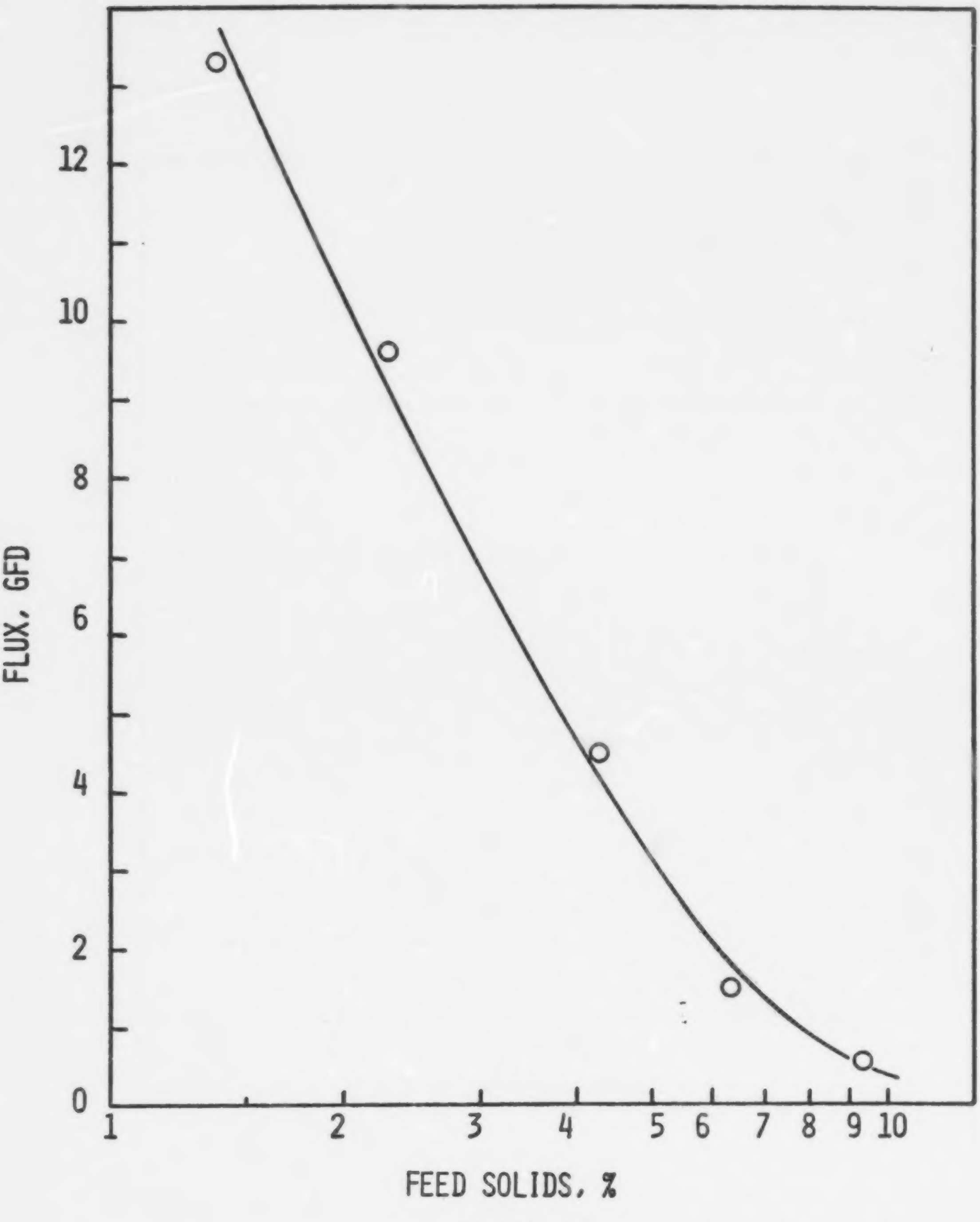

FIGURE 13

LABORATORY REVERSE OSMOSIS DATA

DEPENDENCE OF FLUX ON FEED SOLIDS CONCENTRATION
SOY WHEY - UF PERMEATE AS FEED
OPERATING CONDITIONS: 600 PSI AND 25°C

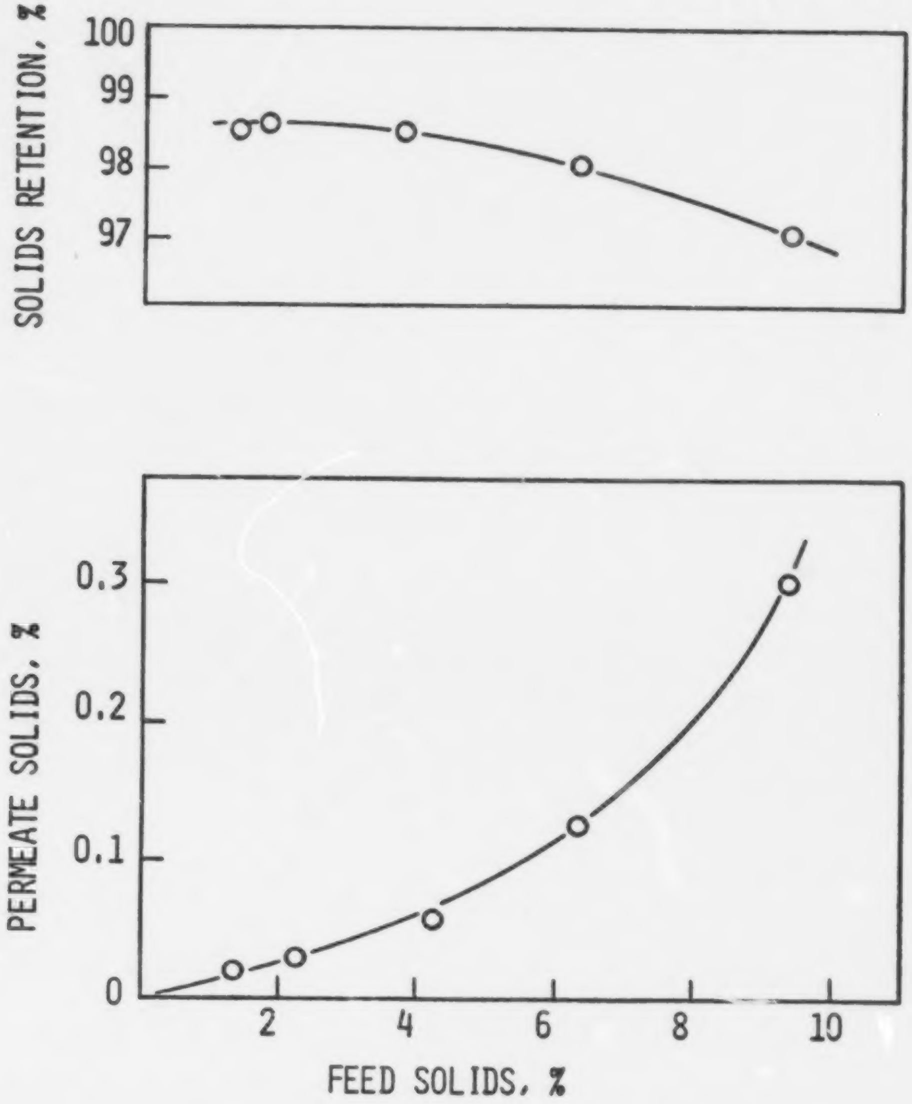

FIGURE 14

LABORATORY REVERSE OSMOSIS DATA - SOLIDS RETENTION
(SOY WHEY - UF PERMEATE AS FEED)
(OPERATING CONDITIONS SAME AS FIGURE 13)

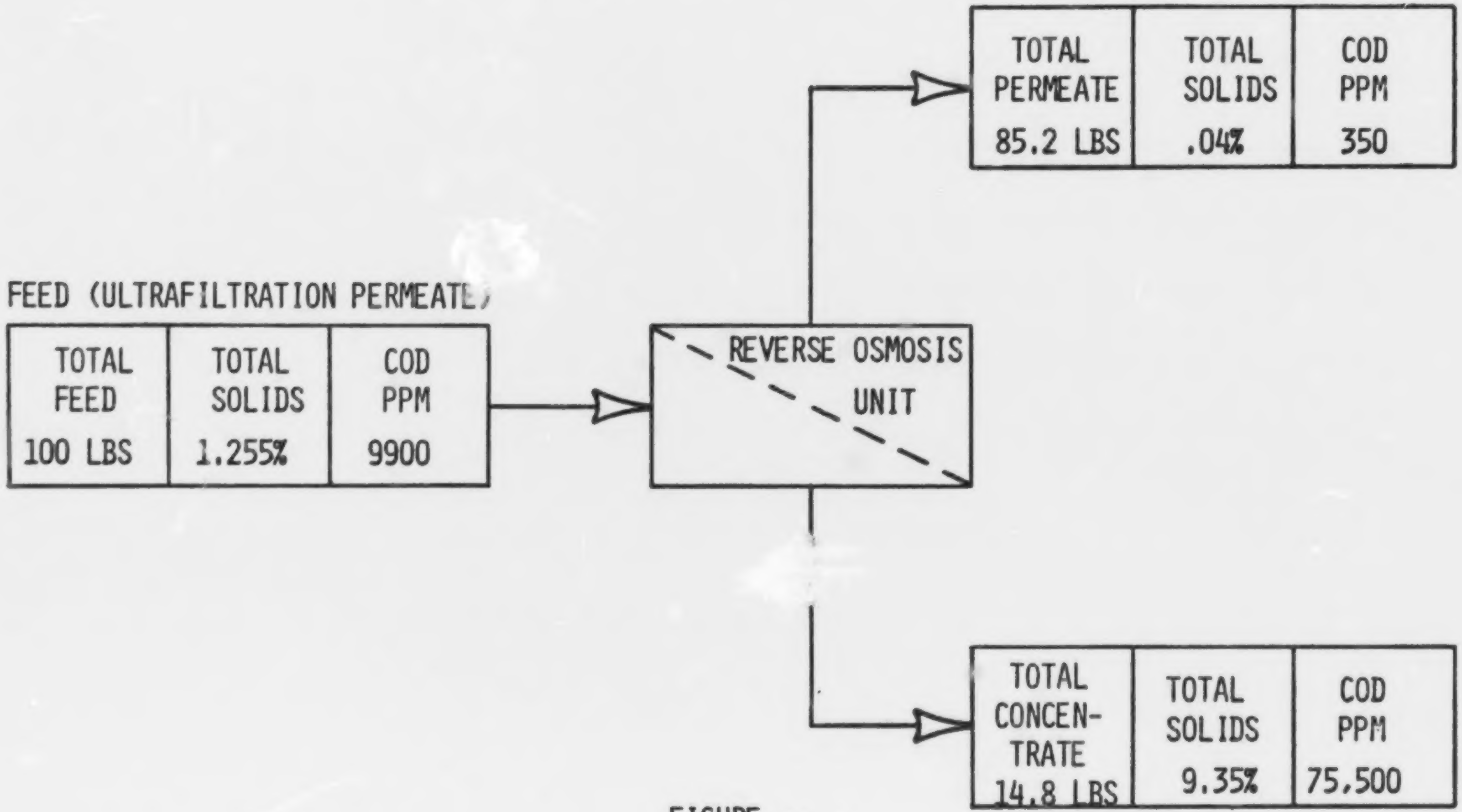
FEED (ULTRAFILTRATION PERMEATE)
TOTAL FEED
100 LBS
TOTAL SOLIDS
1.255%
COD PPM
9900
REVERSE OSMOSIS UNIT
TOTAL PERMEATE
85.2 LBS
TOTAL SOLIDS
.04%
COD PPM
350
TOTAL CONCEN-TRATE
14.8 LBS
TOTAL SOLIDS
9.35%
COD PPM
75,500

FIGURE 15

CONCENTRATION OF SOY WHEY/UF PERMEATE BY REVERSE OSMOSIS - MATERIAL BALANCE

TABLE V

PILOT PLANT REVERSE OSMOSIS DATA
EFFECT OF CONVERSION ON PERFORMANCE

			FEED			CONCENTRATE			PERMEATE		
DATE	FLUX, GFD	OPERATING PRESSURE, PSI	TOTAL SOLIDS, %	BOD, PPM	COD, PPM	TOTAL SOLIDS, %	BOD, PPM	COD, PPM	TOTAL SOLIDS, %	BOD, PPM	COD, PPM
7/26/71	10	600	0.86	5250	8,236	1.31	8,000	12,600	0.02	86	192
2/10/72	5.5	720	0.86	4150	10,000	3.00	15,200	27,200	0.07	250	540
8/9/71	4.4	660	0.93	3850	9,790	8.53	35,300	90,000	0.04	165	414
11/24/71	2.1	710	0.99	4300	9,600	12.74	62,000	140,000	0.21	1060	1840

V. CONTINUING WORK

From these data it is apparent that soy whey can be treated in a two-step membrane process to produce protein and sugar concentrates as by-products, as well as a final effluent with greatly reduced oxygen demand. The economic potential of the process is presently under evaluation. The pilot data serve as design bases for costing a full-scale installation. Attractiveness of the process depends on by-product values, which also are presently under investigation.

VI. ACKNOWLEDGEMENTS

The authors acknowledge the financial support provided by the Office of Research and Monitoring of EPA in Grant No. 12060 FUR.

Mr. Clifford Risley and Dr. David Rickles of the Chicago Office of EPA have contributed to the direction and planning of this program.

VII. REFERENCES

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2. "Industrial Ultrafiltration", in Membrane Processes In Industry and Biomedicine; Plenum Press, 1971, pages 267-300.

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FULL-SCALE ANAEROBIC TRICKLING FILTER EVALUATION

by

Dennis W. Taylor*

INTRODUCTION

For the past 15 months the Food Waste Research Section of the National Waste Treatment Research Program, NERC, Corvallis, has monitored the operation of a unique industrial waste treatment system. This "in-house" project was initiated through the cooperation of Centennial Mills wheat starch-gluten plant in Spokane, Washington, and the U. S. Environmental Protection Agency.

ANAEROBIC WASTE STABILIZATION

An anaerobic filter is basically a rock-filled enclosure where, in the absence of oxygen, anaerobic organisms utilize organic wastes by converting them principally to methane, carbon dioxide, and water. The distribution header for the filter is usually located at the bottom, thereby creating an upward flow through the submerged bed of rocks. Very little of the organic matter stabilized is converted to new cells, thus the sludge disposal problem (inherent in aerobic systems) is minimized.

Anaerobic treatment of biodegradable organics is essentially a two-step process. In the first step complex organic materials are converted into simpler organics, primarily fatty acids. Although no waste stabilization occurs during this first stage, it is an essential step in anaerobic digestion. The second step is carried out by a group of bacteria called methane formers. These organisms are more sensitive to environmental insult than acid-forming bacteria and require a number of favorable conditions to function properly. Among the more important of these conditions are pH and temperature.

The primary products of the anaerobic degradation of organics are: gases methane, 70 percent, and carbon dioxide, 20 percent; solids, new cells <0.2 lb/lb COD removed.

Perhaps the most significant advantage of anaerobic treatment involves biomass production. Since the major portion of the waste is converted to methane gas and carbon dioxide only a small amount of waste biological sludge is produced. This markedly reduces the sludge stabilization and disposal problem inherent in an aerobic system. This and other advantages are listed in Table 1.

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*Sanitary Engineer, Food Waste Research Section, National Waste Treatment Research Program, U. S. Environmental Protection Agency, National Environmental Research Center, 200 S.W. 35th St., Corvallis, Oregon 97330.

Table 1. Advantages of Anaerobic Treatment

1. Low production of biological sludge
2. High treatment efficiency
3. Low capital cost
4. No oxygen requirement
5. Methane production (potential source of fuel)
6. Low nutrient requirement
7. Low operating costs
8. Minimal attention required (anaerobic filter)
9. Inherent long solids retention time (anaerobic filter)

The disadvantages of anaerobic treatment of concentrated soluble wastes are relatively few. Three of the more important disadvantages are possible production of malodorous gases, comparatively high operating temperatures, and the system's slow acclimation to environmental changes (e.g., temperature, loading).

WASTE TREATMENT FACILITY

The waste treatment facility at Centennial Mills was designed by Cornell, Howland, Hayes, and Merryfield of Corvallis, Oregon. Total cost of this system, which incorporated some existing equipment, was in the neighborhood of $110,000.

Figure 1 depicts the flow pattern of the facility. As can be seen, in this diagram, the starch plant waste stream is introduced to the system in the mix tank. At this location chemical addition and steam injection are used for pH and temperature control, respectively. From this tank automatic level controls activate pumps which feed the waste to three anaerobic filters in parallel. The filters are rock-filled, wood stave tanks 30 feet in diameter and 20 feet in height. The crushed rock has a size distribution of 2 to 3 inches in the bottom half and 1 to 2 inches in the top half. From the collection header atop the filters the treated waste can be recycled at rates from 0 to 100 percent by simple adjustment of sliding flow diverters. That portion which is not recycled enters a 4000 gallon chlorine contact tank. The chlorine is introduced for odor control and sewer protection from H_2S.

A cross-sectional view of the anaerobic filter tank is shown in Figure 2 while the distribution and collection headers are diagrammed in Figures 3 and 4. For a profile analysis of the wastewater, samples are withdrawn from the taps shown in Figure 3. The requirement for uniform waste application (to reduce short-circuiting) is exemplified in Figure 3 where it is shown that within one quarter-section of the distribution header, forty-three 1/4 inch holes introduce waste to the filter. Figure 4 depicts the positioning of the collection header ports.

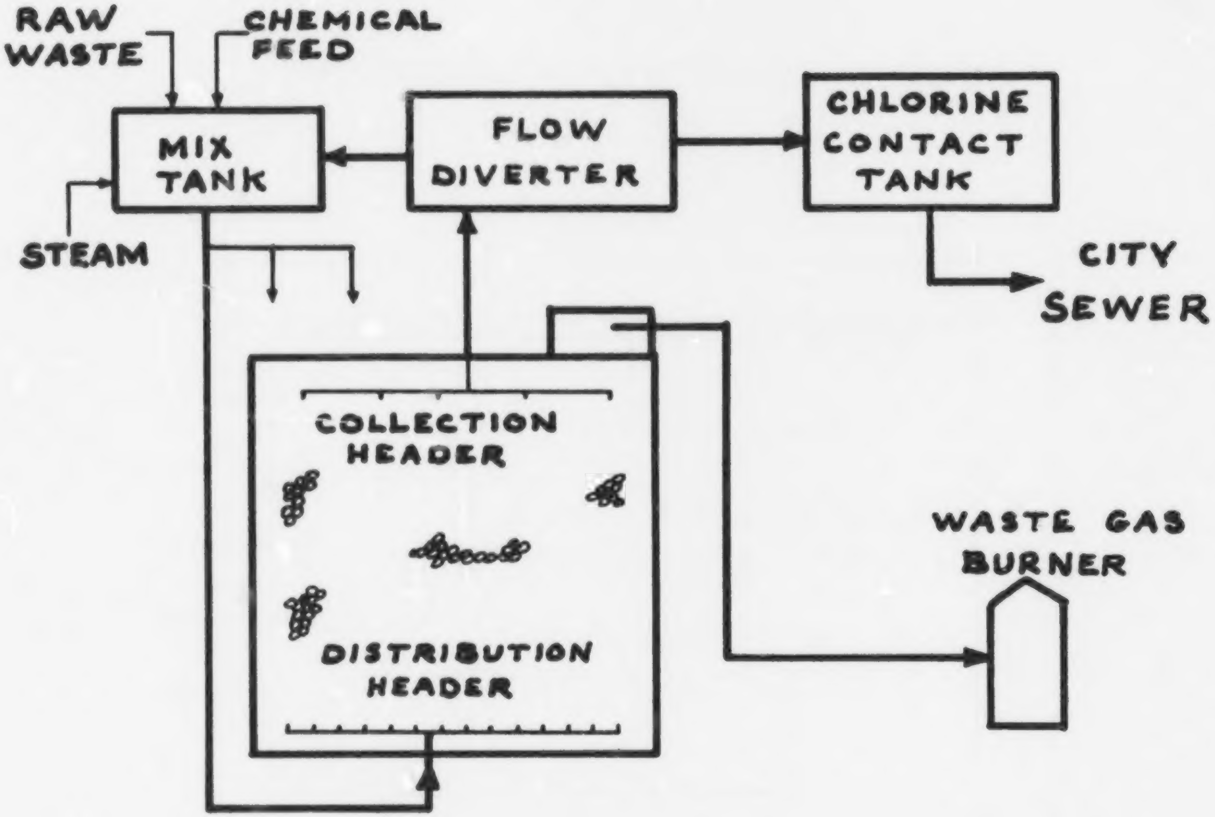
RAW WASTE
CHEMICAL FEED
STEAM
MIX TANK
FLOW DIVERTER
CHLORINE CONTACT TANK
CITY SEWER
COLLECTION HEADER
DISTRIBUTION HEADER
WASTE GAS BURNER

FIGURE 1

ANAEROBIC FILTER TREATMENT
SYSTEM
CENTENNIAL MILLS

10-71

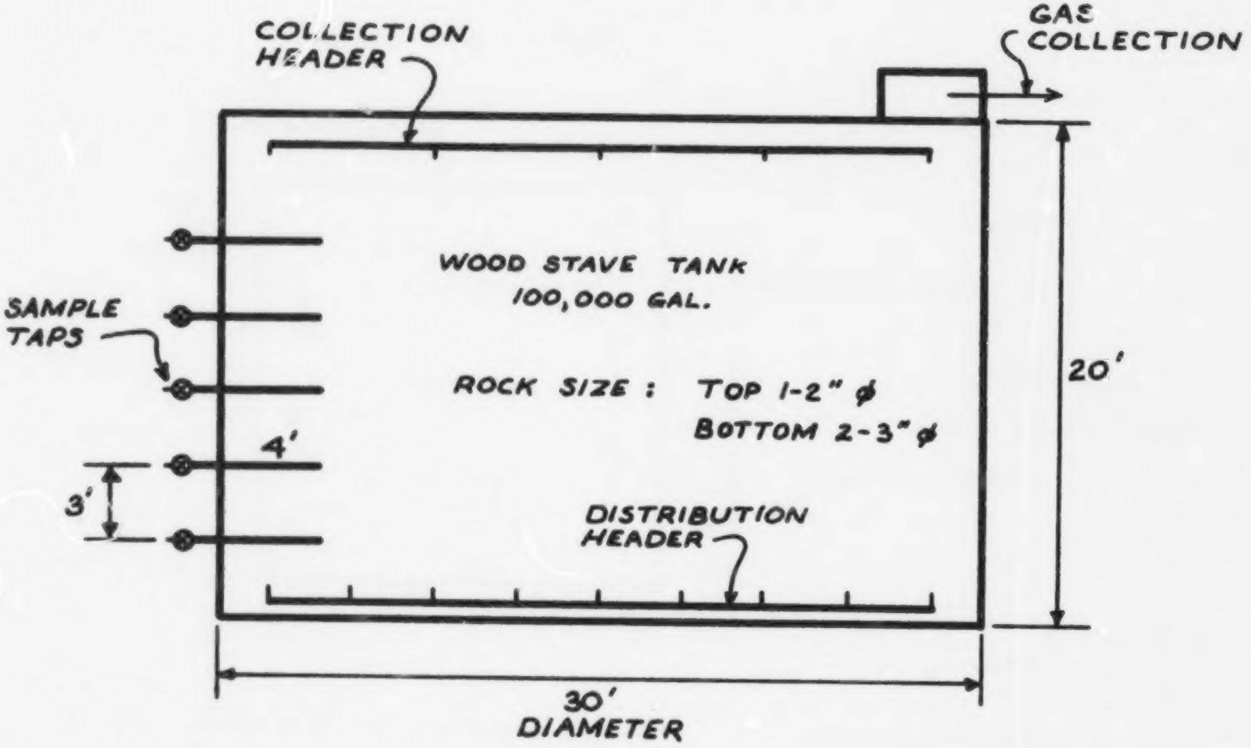
COLLECTION HEADER
GAS COLLECTION
WOOD STAVE TANK
100,000 GAL.
ROCK SIZE : TOP 1-2" ϕ
BOTTOM 2-3" ϕ
SAMPLE TAPS
4'
3'
DISTRIBUTION HEADER
20'
30' DIAMETER

FIGURE 2
ANAEROBIC FILTER CROSS-SECTION

10-71

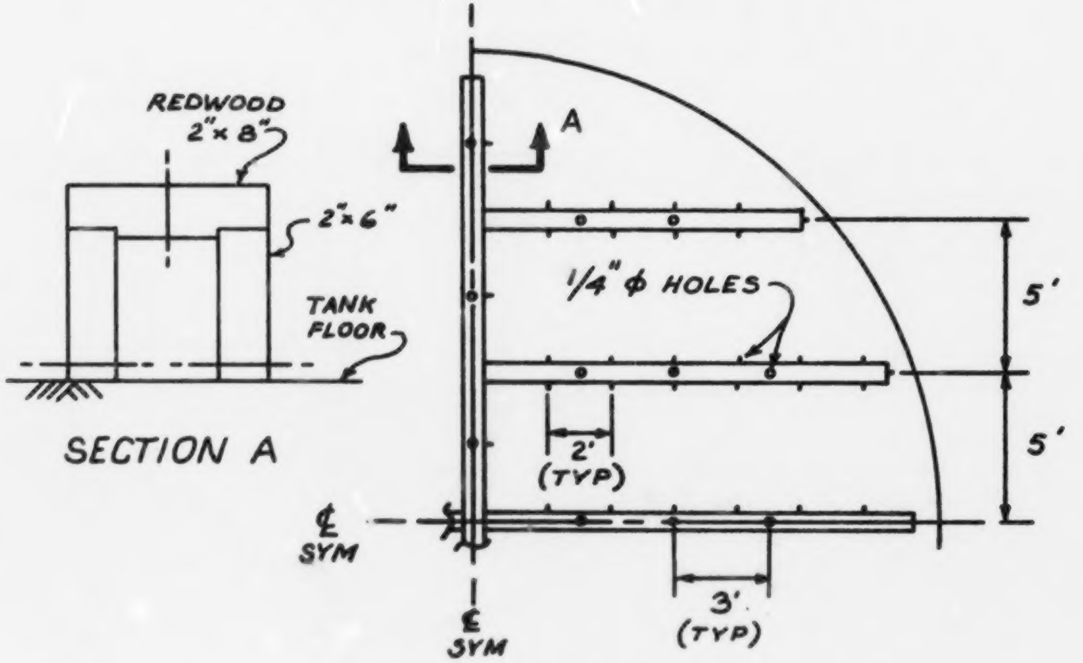
REDWOOD 2"×8"
2"×6"
TANK FLOOR
SECTION A
A
1/4" ϕ HOLES
5'
5'
2' (TYP)
3' (TYP)
℄ SYM
℄ SYM

FIGURE 3
DISTRIBUTION HEADER

10-71

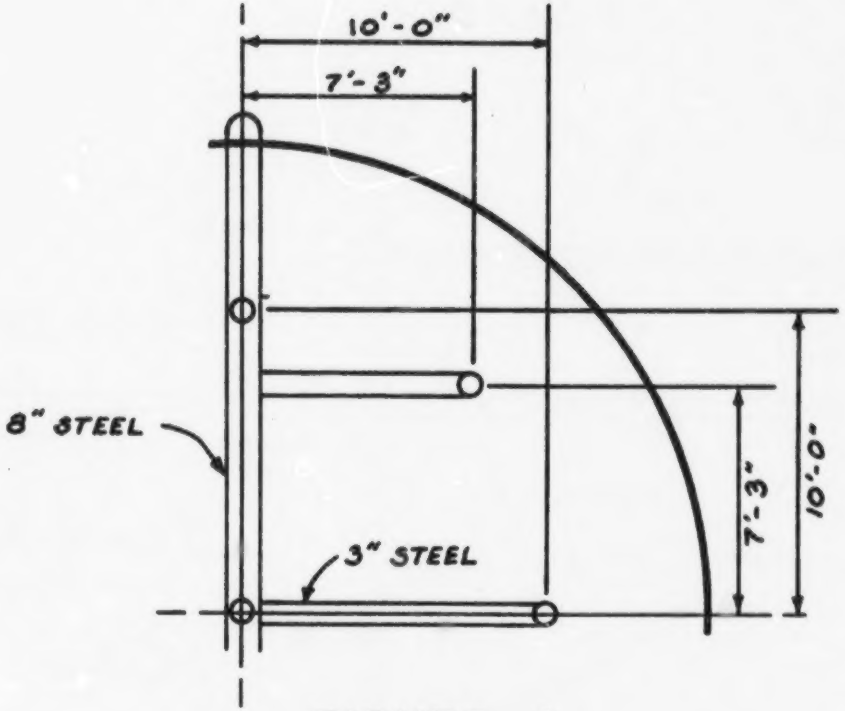
10'-0"
7'-3"
8" STEEL
3" STEEL
7'-3"
10'-0"

FIGURE 4
COLLECTION HEADER

10-71

No attempt is made to recover the energy available from the methane gas produced. The gas, estimated at 30,000 cubic feet per day, is burned.

Following completion of construction in January 1971 the anaerobic filters were filled with water, heated (85°F) and 2500 gallons of screened anaerobic sludge were then added to each filter.

The startup waste-acclimatization period lasted approximately 45 days after which time the treatment facility was accepting the entire waste flow. During this period sodium bicarbonate was added to maintain pH level and sufficient alkalinity. Nitrogen was also added to the system first in the form of anhydrous ammonia then as pelletized urea.

Normal operation consisted of no recirculation during the week and 100 percent recirculation when the starch plant was shut down for weekends or for repairs. Chemical addition rates were 42 lbs/hr for sodium bicarbonate and 30 lbs/hr for urea.

At one point the starch plant shut down operations for approximately 30 days. The filter pumps were turned off so that no recirculation occurred during this resting period. To determine the ability of the anaerobic filter to function efficiently after prolonged resting periods, the entire waste flow was sent to them upon plant startup. Within three hours the waste gas burner was in full operation and removal efficiencies approximated those existing prior to the plant shut down.

Some overflows of the mix tank occurred due to the foamy nature of the heated and agitated starch plant waste. The filter pumps were automatically activated by contact probes located within the mix tank. Until these probes were encased in a stand pipe and washed continually with a fine water spray problems occurred.

Gas leakage from the wood stave filter tanks was cured by additional sealing of the tank tops.

Anhydrous ammonia originally used as a nutrient (nitrogen) source had to be replaced when a hard precipitate built up within the filter pumps. The scale developed to a degree requiring shutdown for cleaning. After replacing the liquid ammonia with urea the precipitate vanished.

Removal efficiency dropped markedly during a short period when the filters were apparently overloaded. Due to the combination of excessive load and a breakdown of the $NaHCO_3$ buffering system the pH of the filter effluents dropped below 6.0 for six days. The pH level was as low as 4.8 during this period. Reducing the loading and adding excess $NaHCO_3$ caused the pH level to climb back to near neutral. At this time removal efficiencies were back to normal.

Malodorous conditions were prevalent during the initial phases of operation. Until the tanks were adequately sealed and the gas burner properly adjusted, a characteristic H_2S odor was present.

Table 2 lists the various volumes and loadings associated with this system. The loading of 237 lb COD/1000 cu ft/day is higher than the normal loading rates of either the activated sludge or trickling filter systems.

Although solids retention time, SRT, (total weight of suspended solids within system ÷ weight suspended solids leaving system per day) is an important parameter for design and control of anaerobic systems there exists no simple mode for its determination for anaerobic filters. SRT's of up to 100 days or more are commonly reported in the literature (1). These figures are derived from laboratory scale models.

Table 2. Anaerobic Filter Volumes & Loadings

Total Filter Volume (3 filters)	300,000 gal	40,100 ft^3
Total Voids Volume (estimate)	120,000 gal	16,000 ft^3
Total Flow	90 gpm	0.13 mgd
Hydraulic Detention Time (theoretical)	22 hr	0.92 day
Filter Temperature	90°F	32°C
Chemical Oxygen Demand	8800 mg/l	9500 lb/day
Biochemical Oxygen Demand$_5$	6500 mg/l	7000 lb/day
Suspended Solids	2650 mg/l	2800 lb/day
Loading/Volume	237 lb COD/1000 ft^3/day	

Listed in Table 3 are some of the effluent characteristics of the anaerobic filters.

Table 3. Anaerobic Filter Effluent Characteristics

Chemical Oxygen Demand	3170 mg/l	3400 lb/day
Chemical Oxygen Demand (filtered)	47%	
Biochemical Oxygen Demand$_5$	2930 mg/l	3100 lb/day
Suspended Solids	1460 mg/l	
Volatile Suspended Solids	87%	
Temperature	87°F	

Comparing the COD values of the filter influent and effluent (Tables 2 and 3) an average removal of 64 percent was measured.

Limited investigations of COD removal vs filter height indicated that although the major portion of waste reduction occurred within the lower levels of the filter, further reduction was evident in the upper levels.

A short-term (30 minute) laboratory sedimentation step, using filter effluent, revealed that increased efficiency could result by incorporating this step. An additional 10 percent COD removal was obtained. The average suspended solids level of the test samples was 1300 mg/l. After the 30 minute settling period the suspended solids concentration was reduced to 370 mg/l.

CENTENNIAL MILLS STARCH-GLUTEN PLANT

Since much of the starch plant's equipment and process mode is of a proprietary nature, little can be said relative to the manufacturing methods. The plant's input is wheat flour and the method of starch separation is centrifugal. The plant operates three shifts per day and is shut down for cleaning and maintenance during weekends.

Average values for various waste parameters are listed in Table 4. These values are consistent with those found in the literature. The values in the table were derived using 24-hour composite samples except as noted. The samples were collected in iced containers at 18 minute intervals. Since the mechanics of plant operation dictate nearly constant flows to the treatment system, the samples are assumed to be "true" composites.

Table 4. Centennial Mills Starch Plant Effluent Characteristics

	Frequency of Analyses	
Flow (gpm)	Daily	90
(mgd)		0.13
COD (mg/l)	2/wk	8800
(#/day)		9500
Centrifuged COD (mg/l)	2/wk	6200
(#/day)		6600
BOD (mg/l)	1/wk	6500
(#/day)		7000
pH*	Daily	>7
Temperature* (°F)	Daily	70
(°C)		21
Total Kjeldahl nitrogen as N (mg/l)	1/month	370
(#/day)		400
Ammonia nitrogen as N (mg/l)	1/month	20
(#/day)		21
Total phosphorus as P (mg/l)	1/month	75
(#/day)		80
Alkalinity* (mg/l)	Daily	680
Volatile acids* †	Daily	355
Suspended solids (mg/l)	2/wk	2650
(#/day)		2800
Volatile suspended solids (mg/l)	2/wk	2500
(#/day)		2700

---

* Grab samples

† All analyses were conducted per EPA (2) except volatile acids, where the method of DiLallo and Albertson (1) was used.

CONCLUSIONS

1. An anaerobic filter can be successfully used to treat high strength wheat starch-gluten plant waste.

2. No apparent loss of efficiency occurred after a "resting" period of one month.

3. Potential odor problems can be controlled.

4. Greater than 60 percent organic removal efficiency was obtained with an average suspended solids concentration of 2600 mg/l in the influent.

REFERENCES

1. DiLallo, Rosemarie and O. E. Anderson. Volatile acids by direct titration. Water Pollution Control Federation Journal, Vol. 33, No. 4, 356-365. 1961.

2. Environmental Protection Agency. Water Quality Office. Analytical Quality Control Laboratory. Methods for chemical analysis of water and wastes. Cincinnati, Ohio. 1971.

3. McCarty, Perry L. Anaerobic treatment of soluble wastes. In: Advances in Water Quality Improvement, University of Texas Press, Austin, Texas. 1968.

ICE CREAM WASTEWATER CHARACTERIZATION AND TREATABILITY

by

E. F. DUL*

INTRODUCTION

The purpose of this paper is to present the results of a wastewater characterization and treatability study performed on an ice cream processing plant effluent. Particular items of interest are:

- an identification of wastewater sources and characteristics attendant to ice cream processing;
- a description of techniques implemented at the plant to reduce wastes generation;
- a description of the techniques used in waste loading projections and the projections developed for the plant; and,
- the results of alternative aerobic biological treatability studies performed on the wastewater at varying treatment rates and wastes temperature.

PLANT/PRODUCTION INFORMATION

The plant under investigation is located in the Northeast and operates eight hours per day, five days per week. Soft ice cream is the chief production item, with a small quantity of frozen pies also being produced. Ice cream and frozen pie production operations are shown in schematic in Figures 1 and 2.

Ice Cream Processing

The manufacture of ice cream incorporates two basic steps:

- preparation of the ice cream base in vanilla and chocolate flavors; and,
- addition of appropriate ingredients (i.e., fruits, nuts, flavor extracts) to produce a variety of other ice cream types beyond chocolate and vanilla.

Ice cream base is produced by formulating a blend of cream, water, sugar, and additives. The resultant mixture is then pasteurized, homogenized, chilled, and put into interim, refrigerated storage.

Base is withdrawn from storage, as production demands, and is conveyed

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*H. F. Ludwig & Associates/Engineering-Science, Inc., Washington, D.C., Great Neck, New York

Figure 1

SCHEMATIC OF ICE CREAM MANUFACTURE UNIT OPERATIONS & PROCESSES

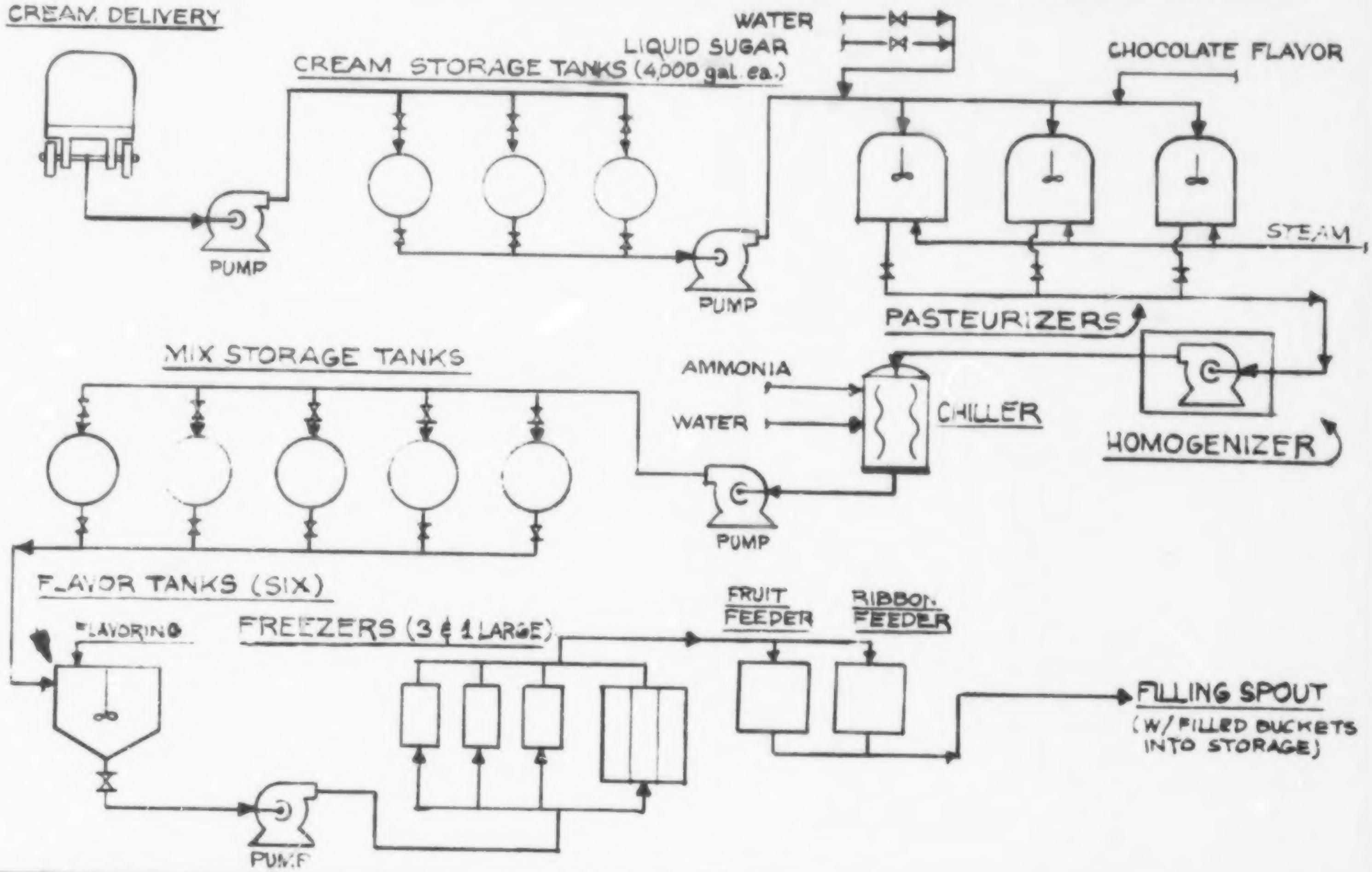
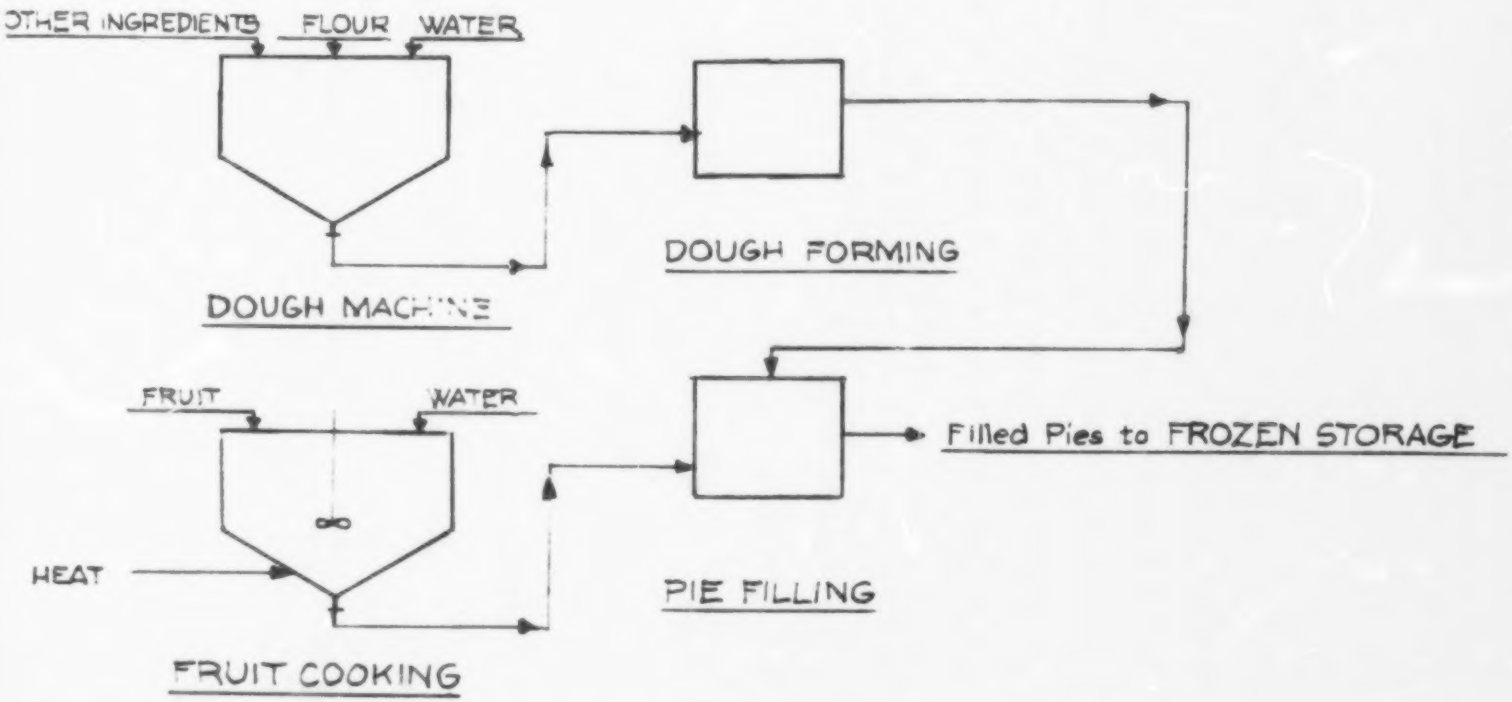

CREAM DELIVERY
PUMP
CREAM STORAGE TANKS (4,000 gal. ea.)
PUMP
WATER
LIQUID SUGAR
CHOCOLATE FLAVOR
STEAM
PASTEURIZERS
AMMONIA
WATER
CHILLER
HOMOGENIZER
MIX STORAGE TANKS
PUMP
FLAVOR TANKS (SIX)
FLAVORING
FREEZERS (3 & 1 LARGE)
PUMP
FRUIT FEEDER
RIBBON FEEDER
FILLING SPOUT
(W/ FILLED BUCKETS INTO STORAGE)

Figure 2

SCHEMATIC OF FROZEN PIE PREPARATION


OTHER INGREDIENTS
FLOUR
WATER
DOUGH MACHINE
DOUGH FORMING
FRUIT
WATER
HEAT
FRUIT COOKING
PIE FILLING
Filled Pies to FROZEN STORAGE

to flavor tanks where the appropriate flavor extract is added. The blend is then passed through freezers to be converted to a semi-solid form and then put into three gallon containers for shipment. Fruits, nuts or a "ribbon" are added to the ice cream, as required, just after freezing and prior to container filling.

Frozen Pie Preparation

As seen in Figure 2, batch fruit preparation (cooking and cooling), dough preparation and forming, pie filling and final product freezing and storage are the unit operations attendant to pie preparation.

WASTEWATER SOURCES

The chief wastewater sources at the plant are as follows:

- Process Wastewater;
- Domestic Wastewater; and,
- Utility Wastewater (i.e., cooling water, boiler blowdown)

The latter two forms of wastewater are segregated from process wastewater and are disposed of separately in a manner that is satisfactory to the controlling regulatory agency. Thus, only process wastewater is discussed in this paper.

Ice Cream Process Wastewater

Wastewater generation in ice cream processing results from cleanup operations which can be divided into two general types:

- General plant cleanup which occurs at the end of the production day. All equipment from the "mix" storage tank discharge pumps to the filling spout is "broken down" and cleaned.
- Sporadic cleanup includes:
    - Tank Truck Cleanup - Whenever a cream tank truck is emptied, it must be hosed clean before leaving the plant.
    - Pasteurizer, Homogenizer, Chiller Flushout - Whenever a run of mix is completed, this equipment must be flushed out. The operation is performed by hosing down each pasteurizer vessel and then pumping the resultant wastewater through the homogenizer and chiller and out to waste.
    - Pasteurizer, Homogenizer, Chiller Rinseout - This operation is performed similarly to a flushout except that it is performed only one time per day regardless of the volume or types of mixes prepared. In this operation, water, detergent and a sanitizer are used to prevent a film buildup in the equipment. No contact with raw ice cream ingredients is made in this operation.

- Mix Storage Tank Cleanup - Whenever a mix storage tank is completely emptied, the tank is hosed down and rinsed with clean water.

- Small Backflush - Whenever a change is to be made in the type of fruit (or nuts) or ribbon to be added to a given flavor ice cream, the fruit or ribbon feeder and the piping from this unit to the filling spout is flushed so that no intermixing of product types is realized.

- Complete Backflush - Whenever a significant change in flavor types is to be made (as for example from vanilla to chocolate), all the piping and equipment between the flavor tank and the filling spout must be cleaned. First a small backflush as described above is performed and then the water hose is fed into the filling spout to pass water through the piping back to the flavor tank discharge valve.

From the foregoing, it should be noted that the number and frequency of the six sporadic type cleanups in an ice cream plant are a function of:

- volume of product handled (i.e., this affects the number of tank truck cleanups and mix storage tank cleanups)
- variations in flavors produced (i.e., this affects the number and frequency of complete backflushes),
- variations in ingredients added to a given flavor ice cream (i.e., this affects the number of small backflushes),
- the type and volume of base mix (vanilla, chocolate or ice) produced (i.e., this affects the number of Pasteurizer, Homogenizer and Chiller Flushouts).

Pie Plant Process Wastewater

Four types of cleanups are performed in the pie plant; slop sink cleanup of utensils, cleanup of fruit cooking vats, general floor cleanup (performed at the end of the day's pie production and subsequent to a dry cleanup of the floor), and pan cleaning performed in the dishwasher. The most significant of these operations in terms of wastewater quantity and strength is the general cleanup.

WASTEWATER CHARACTERISTICS

Source Wastewater Characteristics

Source wastewater characteristics were determined from analysis of waste samples collected on a daily basis from each waste source whenever the operation occurred. The sampling program spanned 2-1/2 months so that all flavor type/ingredient effects could be accounted for. The results of this program in terms of mass emission rates for BOD and Flow are presented in Table 1. As can be seen in Table 1, the general plant cleanup yields the highest unit BOD load as well as a

TABLE 1

ICE CREAM PROCESSING WASTEWATER CHARACTERISTICS

Average Unit Waste Generation

Unit Operation	Unit BOD Load (lbs)	Unit Flow (gals)	Comments
General Plant Cleanup (Major Cleanup)	50	1,000	Occurs one time per day at end of production day.
Tank Truck Wash	1	35	Occurs on receipt of each 4,000 gal. tanker.
Cream Storage Tank Rinse	0	0	Rinsewater conveyed to pasteurizer as part of mix.
Pasteurizer, Homogenizer, Chiller Flushout	18	50	Occurs at end of base flavor run. Maximum number of occurrences equals 3 per day.
Pasteurizer, Homogenizer Chiller Rinseout	0	50	Occurs once per day
Mix Storage Tank Wash	12	50	May occur up to 5 times per day.
Small Backflush	13	650	Occurs up to 6 times per day.
Complete Backflush	25	1,300	Occurs up to 3 times per day.
Pie Shop Cleanup	15	400	Occurs 1 time per day. (Covers approx. 660 ft^2 of production area).
Pan Wash Discharge	1	250	Occurs 1 time per day.

high unit flow. However, more important in terms of their effect on the overall plant wastewater character, are the unit operations that can occur more than one time per day. These operations are:

- Pasteurizer, Homogenizer, Chiller Flushout;
- Mix Storage Tank Wash;
- Small Backflush; and,
- Complete Backflush.

The least significant operations in terms of their impact on overall wastewater character are:

- Tank Truck Wash;
- Pasteurizer, Homogenizer, Chiller Rinseout; and,
- Pan Wash Discharge.

Overall Wastewater Character

Table 2 presents the maxima, minima and average characteristics of the overall process waste stream. The data were acquired over the same 2-1/2 month period utilized to characterize waste source characteristics. Composite samples were obtained by collecting the total daily wastewater volume in the existing, aerated equalization tank. The wide range in data sets shown in Table 2 is caused by the day-to-day variations in the number of small backflushes, complete backflushes, and mix storage tank cleanups that are performed.

An alternative method of presenting the total daily BOD_5 load data [that is later (see WASTEWATER CHARACTERISTICS FORECAST, Method II) shown to be utile in projecting waste loads] is by use of statistical analysis. Figure 3 presents the results of such an analysis. As seen in this Figure, total daily BOD loads, at present, at the plant should not be expected to exceed 400 lbs and 340 lbs more than, respectively, five and ten percent of the time.

Four recommendations were made for improving the wastestream:

- Convey pasteurizer, homogenizer, chiller flushout wastewater (see the earlier section entitled CLEANUP OPERATIONS for description of this operation) to the mix storage tanks rather than to waste.
- Empty the mix storage tanks more completely of their contents before cleanup is initiated.
- Closer mix formulation control should be initiated so that a minimal residual in the flavor tanks remains after production is completed.

TABLE 2

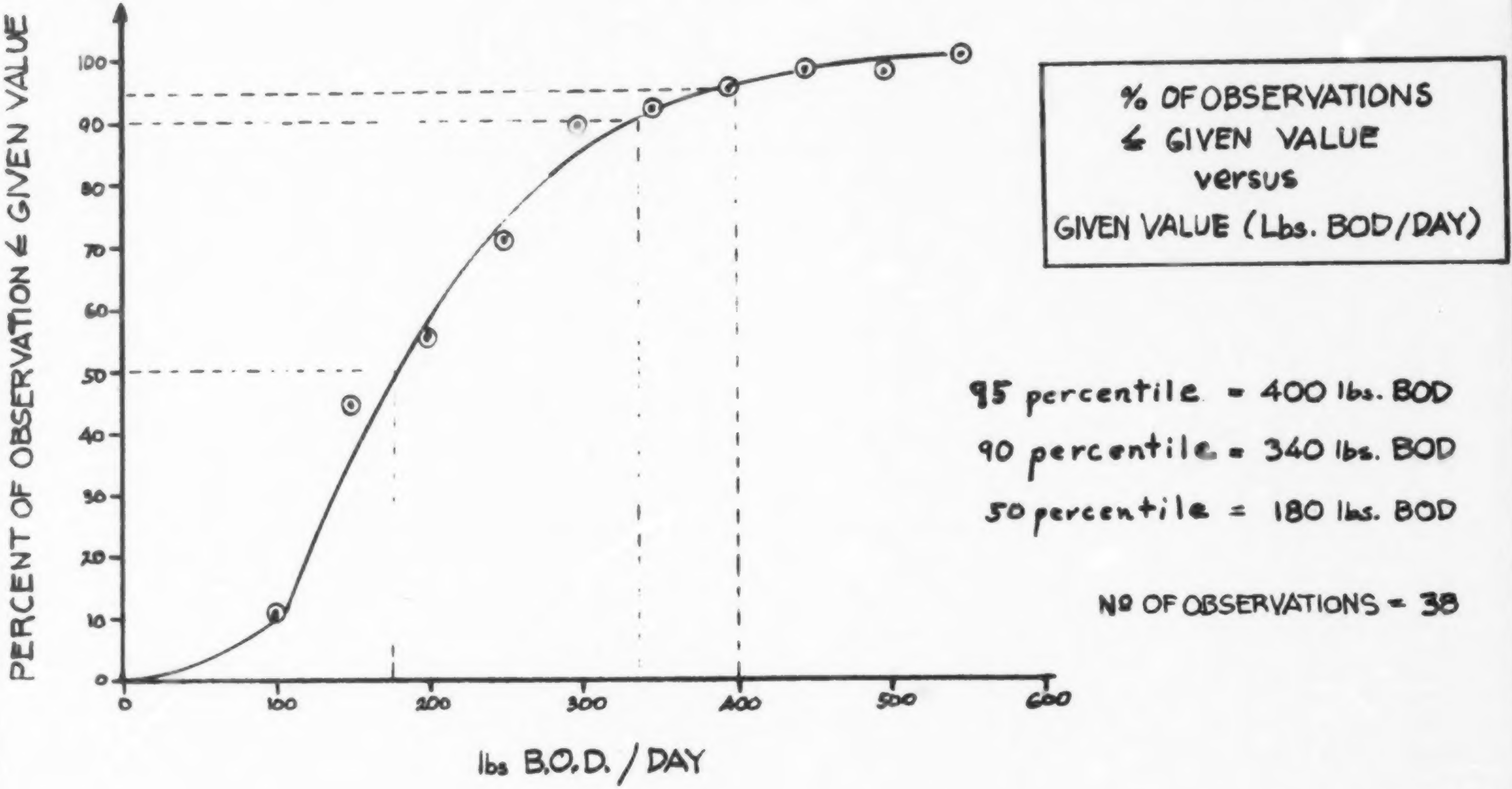
ICE CREAM PROCESSING WASTEWATER CHARACTERISTICS

OVERALL EFFLUENT DATA SUMMARY

Item	Average	Maximum	Minimum	Ratio $\frac{\text{Max.}}{\text{Min.}}$
Total Daily Flow gpd	4,000	5,400	1,950	2.8
BOD (5da.-20°C) (mg/ℓ)	6,200	13,600	2,540	5.3
COD (mg/ℓ)	7,800	17,000	3,220	5.3
BOD (5da.-20°C) lbs/day	207	540	90	6.0
Suspended Solids (mg/ℓ)	1,170	4,820	140	35
Settleable Solids (mg/ℓ)	11	100	0	≈ 100
pH	--	10.6	4.2	2.5

Figure 3

STATISTICAL ANALYSIS OF BOD_5 DATA FOR TOTAL PLANT EFFLUENT



- Automatic steam/water mixing valves should be installed on the hoses which presently do not have them to reduce water wasting when a hose is dropped and left to run.

PRODUCTION AND UNIT OPERATIONS FREQUENCY VS. WASTEWATER CHARACTERISTICS FORECAST TECHNIQUE

In order to develop scale-up data for future wastewater flow and strength, two alternative approaches were employed. The first was to review wastewater generation in terms of the units of production (i.e., determine the unit flow and BOD per unit of finished product). The second approach was to relate wastewater generation to unit operations of production.

Ice Cream Operations

Present production of ice cream is 32,000 gallons per week or approximately 2,000 units per day. Ultimate plant production capacity is expected to be reached in 1975 or 1976 when daily production will be approximately 6,000 units per day (unit equals one 3 gallon ice cream container). Note, however, that it is the cleanup operations which directly affect wastewater volume and strength and these are related to changes in production items and not directly to the volume of production. Thus it was decided that investigation of the frequency of unit production operations was a more precise method of forecasting wastewater characteristics.

Pie Plant Operations

The only significant wastewater source in pie plant operations was found to be the floor cleanup performed at the end of the day's production. Just as in the case of ice cream preparation, the volume and strength of waste is independent of the number of pies produced but is a function of whether or not any pies are made. Although plans exist to expand the pie plant in the future, no expansion of the processing area is intened (Note: Expanding the processing floor area would mean more floor to clean and thus a greater wastewater volume and strength). The expansion will incorporate new office and freezer facilities and a more intensive use of the production area.

WASTEWATER CHARACTERISTICS FORECAST

The previous section defined the type of data to be utilized for forecasting (i.e., waste generated per unit operation). This section describes the data analysis methods used in developing the forecast of wastewater characteristics.

Method I - Unit Process Effects

Using the unit wastes data presented in Table 1 in conjunction with forecasts regarding the frequency of unit operation occurrence in the future, estimates of future waste loads were made. These estimates are shown in Tables 3 and 4. Note that, because of the addition of a new freezer and attendant piping, the unit BOD and flow factors for

TABLE 3

BOD_5 FORECAST

(Based on Unit Operation Waste Data)

Unit Operation	Unit Waste Load (lbs BOD/day)	Future Unit Operation Frequency*	Future Ultimate Waste Load (lbs BOD/day)
Tank Truck Wash	1# BOD/receipt	1 tanker per day	1
Cream Storage Tank	Zero	Zero	Zero
Pasteurization Homogenization Chilling Flushout	18# BOD/flushout	Assume 3 flushouts per day	54
Mix Storage Tank Wash	12# BOD/washout	Assume all 5 tanks washed per day	60
Small Backflush	13# BOD/backflush	Assume 6 per day	78
Complete Backflush	25# BOD/backflush but 2 parallel systems exist ∴ Use: 50# BOD/backflush	Assume 3 per day	150
Major Cleanup	50# BOD/operation	1 per day	50
Pie Shop Cleanup	Use 15#/cleanup for 660 ft^2	Future = same as today	15
			Total 408 lbs BOD per day

*Per analysis with plant manager.

TABLE 4

WASTEWATER FLOW FORECAST

(Based on Unit Operation Waste Data)

Unit Operation	Unit Flow (gals.)	Future Unit Operation Frequency*		Future Ultimate Wastewater Volume (gals/day)
Tank Truck Wash	35 gals/receipt	1 tanker per day		35
Cream Storage Tank	Zero	Zero		Zero
Pasteurization Homogenization Chilling Flushout	50 gals/flushout	Assume 3 flushouts per day		150
Mix Storage Tank Wash	50 gals/washout	Assume all 5 tanks washed per day		250
Small Backflush	650 gals/backflush	Assume 6 per day		3,900
Complete Backflush	1,560 gals/backflush**	Assume 3 per day		4,700
Major Cleanup	1,000 gals/operation	1 per day		1,000
Pie Shop Cleanup	400 gals/cleanup	Future = same as today (1 operation per day)		400
			Total	10,400 gpd

*Per analysis with plant manager.

**Increased from 1300 gals by 20% to account for the extra piping length added by the new freezer.

the complete backflush were adjusted upwards. Using this technique, the projected ultimate BOD_5 and flow were 408 lbs. per day and 10,400 gallons per day, respectively.

Method II - Analyze Total Plant Effluent

BOD

It was felt that a better account of the effects of "accidents" in the plant (which would definitely and most importantly affect wastewater BOD) might be made via a statistical analysis. A statistical analysis was performed on all the raw sampling and analysis data. Additionally, the sampling program was modified so that concentrated wastes generated in the small and complete backflushes and mix storage tank washouts could be collected separately over the day in one separate vessel (an abandoned flavor tank) and sampled separately. Alternately, all other plant wastewaters (called dilute wastewater) were also sampled and analyzed separately. The results of the statistical analyses are shown in Figures 4 and 5. Figure 4 indicates 90 and 95 percentile values of concentrated wastewater BOD per day of 212 lbs. and 220 lbs., respectively. Figure 5 indicates 90 and 95 percentile values of dilute wastewater BOD per day of 139 lbs. and 147 lbs. BOD, respectively.

To develop a scaled-up ultimate design BOD load, the following were noted:

- For dilute washwater the conservative 95 percentile value of BOD of approximately 150 lbs. per day would be recommended for use for ultimate design. This is based on the fact that dilute washwater sources will not significantly change with time (i.e., pie plant cleanup, general plant cleanup, tank truck wash).
- For concentrated wastewater, at present, a 95 percentile BOD of 220 lbs. per day is noted. To account for an increase in the number of small backflushes per day (from five performed on 31 March 1971 when the 95 percentile was exceeded) to an ultimate of six (forecasted by the plant) a scale-up factor of (6/5 =) 1.2 should be used. To account for using all the existing and new freezer capacity at the plant (this affects complete backflushes) rather than only two small freezers and two barrels of the new large freezer (Note: This has been the maximum freezer usage to date) a factor of $\left(\frac{\text{6 freezers total}}{\text{4 freezers presently in use}} =\right)$ 1.5 should be used. Thus, concentrated waste BOD is projected to reach a 95 percentile value of (220 lbs/day x 1.2 x 1.5 =) 400 lbs/day.

The projected ultimate 95 percentile of total plant BOD was thus estimated to be:

Figure 4

STATISTICAL ANALYSIS OF BOD_5 DATA FOR CONCENTRATED WASTEWATERS

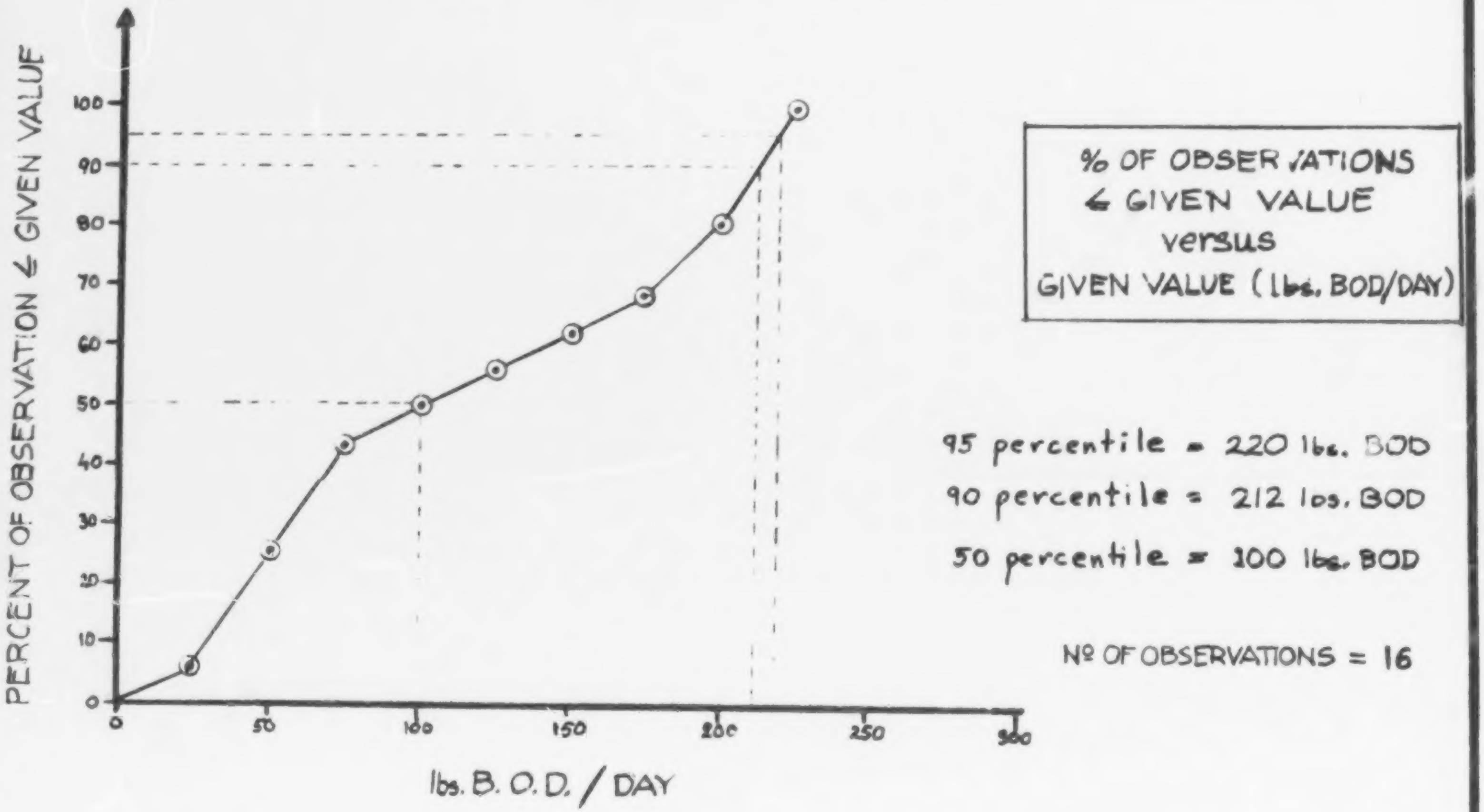
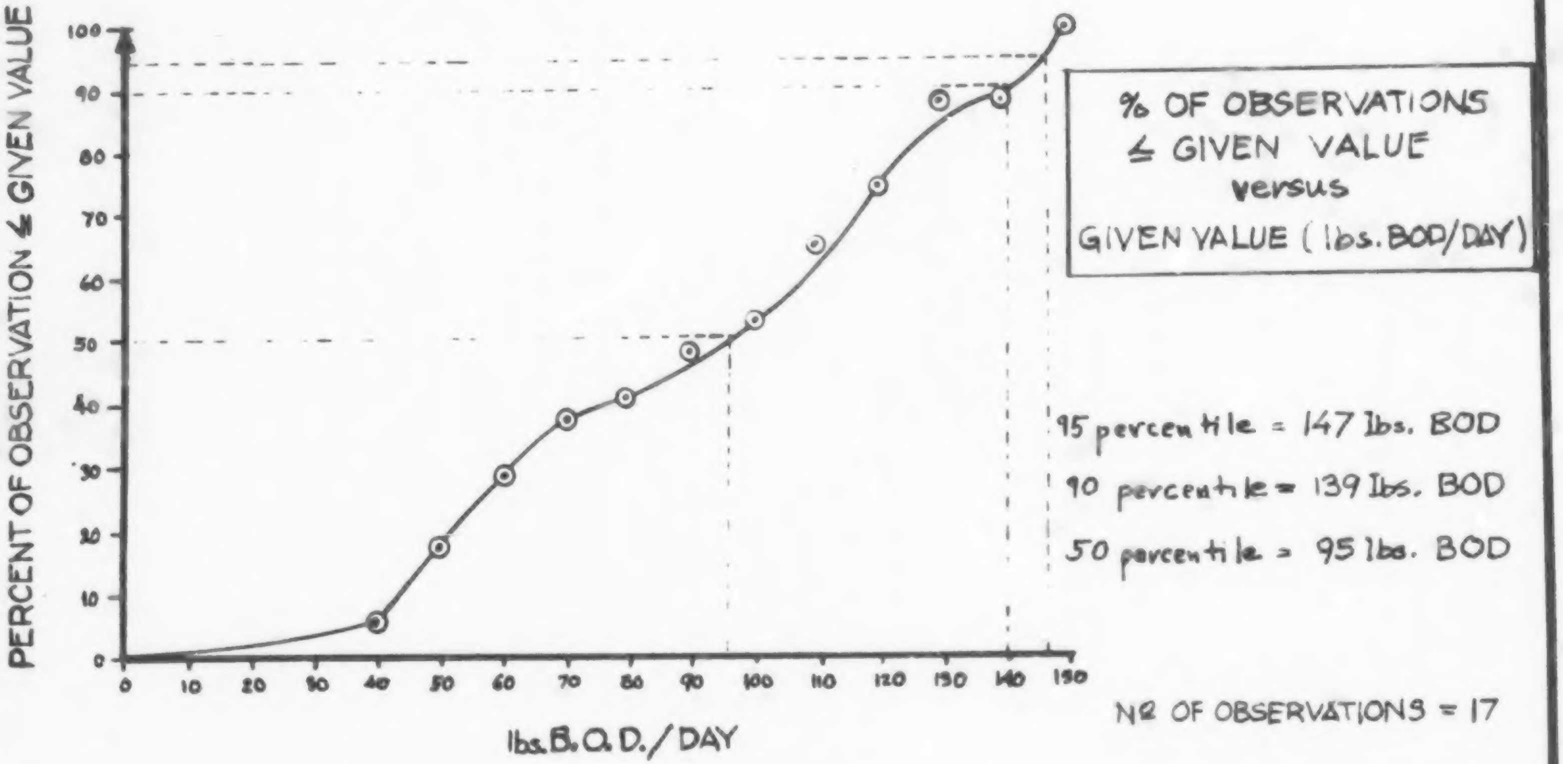


Figure 5

STATISTICAL ANALYSIS OF BOD_5 DATA FOR DILUTE WASTEWATERS



95 percentile = 147 lbs. BOD
90 percentile = 139 lbs. BOD
50 percentile = 95 lbs. BOD

Nº OF OBSERVATIONS = 17

Dilute Washwater	150 lbs. per day
Concentrated Wastewater =	400 lbs. per day
Total	550 lbs. per day

ALTERNATIVE WASTEWATER TREATMENT AND DISPOSAL TECHNIQUES

Throughout the study period as data accumulation and analysis progressed, alternative wastewater treatment and/or segregation and disposal techniques were reviewed. The chief alternatives that came under review were:

Alternative I - Treatment of the total daily wastewater on-site in an extended aeration type aerobic biological treatment plant.

Alternative II - Treatment of dilute washwaters on-site in an extended aeration type aerobic biological treatment plant while concentrated wastewater is treated on-site in an anaerobic fermentation treatment plant.

Alternative III - Treatment of dilute washwaters on-site in an extended aeration type aerobic biological treatment plant while concentrated wastewater is collected for disposal off-site.

Alternative I was selected as the optimum treatment system for the following reasons:

- Published data (1) indicate that an extended aeration type aerobic biological treatment plant will produce a high quality effluent that will meet the demands of the controlling regulatory agency.
- Annual costs (amortized capital and annual operation and maintenance) for Alternative I would be the least and could be more reliably projected than those for the other alternatives. (Especially as regards Alternative III, off-site disposal costs are subject to increase with time.)
- Alternative I requires the simplest operation and maintenance expenditures and labor talent.
- Alternative I has the highest "shock absorbing" capacity of all the alternative systems studied. The plant will be able to sustain the effects of in-plant accidents (i.e., accidental fruit or mix spills) without requiring the plant personnel to call for outside assistance (i.e., emergency scavenger calls to pump out an overloaded treatment plant).

LABORATORY TREATABILITY STUDIES

General

In order to define the efficiency of the proposed extended aeration system under various operating conditions, a three component treatability study was developed and implemented.

Phase I of the study was designed to operate at a Food: Microorganism (F/M) ratio averaging at 0.07 (Note: From correlations, BOD = 0.8 COD). A five liter aerobic reactor was utilized and reactor contents were maintained at room temperature. In order to simulate field conditions, the total daily feed volume (i.e., 200 mℓ) was fed to the reactor in four equal doses of 50 mℓ each over an eight hour period. No feed was made to the system for the other sixteen hours per day or over the weekend. The system was operated utilizing actual raw plant waste (Note: Concentrated wastes were collected in the field and diluted in the laboratory). The resultant hydraulic retention time was approximately 25 days and nutrient nitrogen was added to the system to maintain a BOD: N ratio of 20:1.

Phase II of the treatability studies was designed to simulate long term shock loading conditions. After operating the Phase I system for approximately one month, the loading was then increased to a total of 500 mℓ per day. All other Phase I conditions were maintained. The average F/M ratio during this period was 0.31 and the hydraulic retention time was reduced to 10 days.

Phase III of the treatability studies was designed to determine the effects of low temperature on the Phase I system. Phase III was implemented by reverting from the Phase II to Phase I loading conditions, equilibrating and then putting the reactor into a refrigerator maintained at 2°-4° C. The results of all the foregoing are presented in the following sections.

Phase I Results

Phase I operating results are presented in Table 5. Over the period of 6 May through 9 June, an average mixed liquor volatile suspended solids (MLVSS) of 2,290 mg/ℓ was maintained in the reactor. With an influent COD averaging at approximately 5,050 mg/ℓ (i.e., BOD averaging at 4,050 mg/ℓ) over this same period, the food-to-microorganism (F/M) ratio in the system was:

$$\frac{F}{M} = \frac{\#\text{BOD}}{\#\text{MLVSS}} = \frac{4050 \text{ mg}/\ell \times 0.2\ell}{2290 \text{ mg}/\ell \times 5\ell} = 0.07$$

COD removals throughout this period ranged from a low of 93.0 percent to a high of 97.7 percent with an average of 95.8 percent. Good settling of the resultant sludge was reported once the system reached equilibrium (starting 21 May) yielding an average Sludge Volume Index (SVI) of approximately 160.

Another important result of the study can be seen by inspecting COD removal efficiency data over weekend periods. The data in Table 5 indicate that insignificant changes in the system efficiency resulted over the weekend periods in spite of the fact that no waste was fed to the system over the weekend in an attempt to simulate actual field conditions.

TABLE 5

ICE CREAM PROCESSING WASTEWATER

EXTENDED AERATION TREATABILITY STUDY RESULTS (F/M = 0.07; 68° F)

DATE	pH	SETTLE-ABILITY ml/l	TSS mg/l	VSS mg/l	INFLUENT COD mg/l	EFFLUENT COD mg/l	% COD REMOVAL
5-6	6.1	980	4880	4100	-	-	-
5-7	6.0	980	4380	3700	-	-	-
5-8	-	-	-	-	-	-	-
5-9	-	-	-	-	-	-	-
5-10	5.35	980	4267	3633	5390	167	96.9
5-11	5.6	980	4300	3640	5200	144	97.2
5-12	5.25	985	4400	3600	4960	310	93.7
5-13	5.2	980	4200	3550	4930	188	96.2
5-14	5.2	980	3700	3200	4900	330	93.2
5-15	-	-	-	-	-	-	-
5-16	-	-	-	-	5096	333	93.4
5-17	5.1	970	3200	2600	5350	310	94.2
5-18	5.0	970	3150	2900	5400	312	94.2
5-19	4.9	920	3050	2550	4940	384	92.2
5-20	4.8	920	2860	2400	5300	368	93.0
5-21	4.7	380	2750	2220	5280	220	95.8
5-22	-	-	-	-	-	-	-
5-23	-	-	-	-	-	-	-
5-24	4.6	520	2580	2100	5352	192	96.4
5-25	4.6	760	2430	2020	5450	190	96.5
5-26	4.3	400	2530	2030	4840	120	97.5
5-27	4.6	350	2420	1860	5340	176	96.7
5-28	4.5	320	2150	1780	5300	160	97.0
5-29	-	-	-	-	-	-	-
5-30	-	-	-	-	-	-	-
5-31	4.5	300	1900	1700	5150	120	97.7
6-1	4.9	300	2070	1650	5060	140	97.2
6-2	4.6	290	2150	1820	4940	192	96.1
6-3	4.55	250	1980	1720	5080	176	96.5
6-4	4.75	230	1718	1180	5340	140	97.4
6-5	-	-	-	-	-	-	-
6-6	-	-	-	-	-	-	-
6-7	4.2	240	2010	1490	3240	140	95.7
6-8	4.3	230	1970	1625	4500	150	96.6
6-9	4.3	220	1750	1420	4980	150	97.0
AVG.	-	342	2762	2290	5054	212	95.8

Phase II Results

The results of the Phase II (i.e., shock loading condition) operations are presented in Table 6. Except for the first day of operation wherein the COD removal efficiency dropped to 88.0 percent from 97.0 percent on the previous day, no adverse effects on system operation were noted. For the two-week period following the first increase in loading, the system COD removal efficiency ranged from a low of 91.4 percent to a high of 95.6 percent, with an average of 94.0 percent. System operating parameters were as follows:

Average MLVSS 1038 mg/ℓ

Average Influent COD = 4072 mg/ℓ

Average Influent BOD = 3250 mg/ℓ

$$\text{Average } \frac{F}{M} = \frac{3250 \text{ mg}/\ell \times 0.51}{1038 \text{ mg}/\ell \times 5.01} = 0.31$$

The sludge settleability was found to be very good with an average SVI of 63. Again, no adverse effects were noted as a result of "starving" the system over the weekend.

Phase III Results

The results of the Phase III (i.e., chilled conditions) treatability program are presented in Table 7. Inspection of the data in Table 7 indicates that the COD removal efficiency ranged from a low of 88.9 percent to a high of 95.6 percent and averaged at 93.0 percent. Sludge settleability was again found to be very good with a resultant SVI of 72. Weekend "starving" of the system produced no adverse effects. The system was maintained at an average F/M ratio of approximately 0.14.

The chilling study results were compared with the work of Clark, et al(2). Clark concluded that, "...several investigations have collected data for aerated lagoon operation performance within the temperature range of 0° C to 10° C...the curves [in Figure 6] demonstrate that there is a high probability for obtaining BOD removal efficiencies greater than 80 percent at detentions less than 15 days with lagoons operating at temperatures less than 5° C." The results of the Phase III program compare favorably with the data/conclusions reported by Clark.

CONCLUSIONS

The most significant conclusions that can be drawn from the foregoing are as follows:

- Ice cream wastewater characteristics are chiefly a function of the type and number of cleanup operations performed.
- Opportunities do exist for wastewater volume and strength reduction in an ice cream processing plant. However, the potential

TABLE 6

ICE CREAM PROCESSING WASTEWATER

HIGH RATE TREATABILITY STUDY RESULTS (F/M = 0.31; 68° F)

DATE	pH	SETTLE-ABILITY (mℓ/ℓ)	TSS mg/ℓ	VSS mg/ℓ	INFLUENT COD mg/ℓ	EFFLUENT COD mg/ℓ	% COD REMOVAL
6-10	4.6	155	1925	1075	5920	712	88.0
6-11	5.1	150	1680	1500	4960	220	95.6
6-12	-	-	-	-	-	-	-
6-13	-	-	-	-	-	-	-
6-14	5.2	80	1220	1020	4720	214	95.5
6-15	-	70	1550	1075	4080	196	95.2
6-16	6.0	70	1400	1200	4000	180	95.5
6-17	-	80	1200	1025	3360	160	95.2
6-18	6.1	70	1130	900	3240	236	92.7
6-19	-	-	-	-	-	-	-
6-20	-	-	-	-	-	-	-
6-21	-	64	1430	1180	3600	192	94.7
6-22	5.0	70	1000	600	3160	148	95.3
6-23	5.0	70	1100	900	3320	170	94.9
6-24	5.75	65	1350	950	4120	352	91.4
AVG.	-	86	1362	1038	4072	244	94.0

TABLE 7

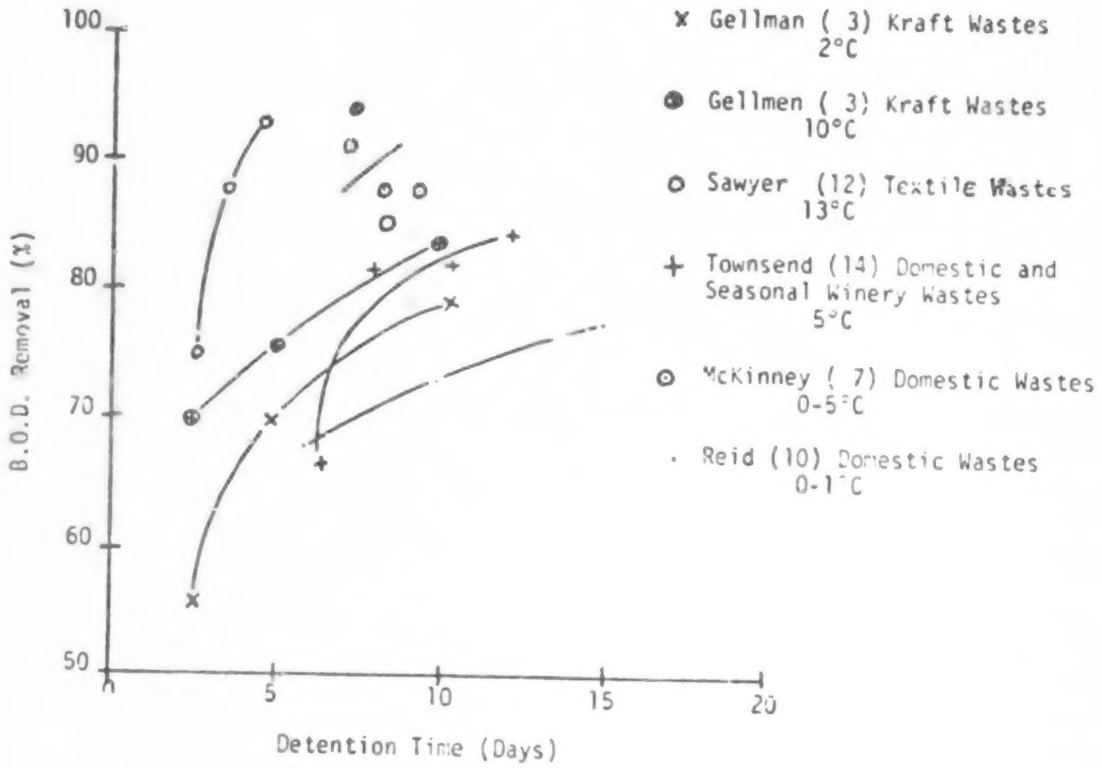
ICE CREAM PROCESSING WASTEWATER

"WINTER" OPERATING RESULTS FOR EXTENDED AERATION (F/M = 0.14; 2°C - 4°C)

DATE	TEMP(°C)	pH	SETTLE-ABILITY mℓ/ℓ	TSS mg/ℓ	VSS mg/ℓ	INFLUENT COD mg/ℓ	EFFLUENT COD mg/ℓ	% COD REMOVAL
7-7	4	7.5	50	-	-	2740	212	92.3
7-8	4	-	60	1010	713	3100	320	89.7
7-9	3	-	-	1215	1000	2760	308	88.9
7-10	-	-	-	-	-	-	-	-
7-11	-	-	-	-	-	-	-	-
7-12	2	-	60	1020	-	2880	216	92.5
7-13	3	-	-	1030	715	3340	210	93.7
7-14	2	-	-	1115	800	3260	204	93.7
7-15	4	-	90	1230	1030	3230	180	94.4
7-16	4	-	80	1280	1040	2680	180	93.3
7-17	-	-	-	-	-	-	-	-
7-18	-	-	-	-	-	-	-	-
7-19	2	6.1	85	1285	865	2960	150	94.9
7-20	4	6.1	70	900	780	5580	428	92.3
7-21	3	5.8	80	910	806	5680	248	95.6
7-22	4	5.6	70	766	613	5120	332	93.5
7-23	4	5.4	90	900	860	4768	384	91.9
7-24	-	-	-	-	-	-	-	-
7-25	-	-	-	-	-	-	-	-
7-26	2	-	-	930	900	5472	338	93.8
7-27	3	5.6	100	1133	1013	5810	296	94.9
AVG.	-	-	76	1051	856	3958	277	93.0

Figure 6

AERATED LAGOONS
PERFORMANCE EFFICIENCIES (2)



for accidental raw/finished product spills should not be underestimated.

- Overall wastewater characteristics in an ice cream plant are highly variable because of day-to-day changeovers in types and quantities of ice cream produced.

- COD removal efficiencies of 94-96 percent can be achieved in aerobic biological treatment units handling ice cream wastewaters at F/M ratios in the range of 0.07 to 0.31.

- No significant change in system operating efficiency resulted when a pilot extended aeration plant (operating an ice cream wastewater) was operated at room (20° C) and subsequently under cold (2°-4° C) temperatures.

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2. CLARK, S.E., COUTTS, H. J., JACKSON R., Alaska Sewage Lagoons presented at the "2nd International Symposium For Waste Treatment Lagoons", sponsored by Missouri Basin Engineering Health Council & Federal Water Quality Administration, June 23-25, 1970, Kansas City, Missouri.

THE USE OF CHEMICAL TREATMENT AND AIR FLOTATION FOR THE CLARIFICATION OF FISH PROCESSING PLANT WASTE WATER

by

F. G. Claggett*

INTRODUCTION

The water used by fish processing plants may be a source of pollution if released into confined waters because of the large volumes and the high levels of organics involved. The effects on the benthic environment of discharges from plants located on seacoasts and river estuaries has been shown to be relatively harmless (9,10).

An analysis of the effluent from almost any fish processing operation shows that the water contains discrete particles of fish ranging from screen to colloidal in size, free fish oil, soluble proteins, sugar phosphates, mineral salts, and various emulsions of these. The extent of each component will vary depending mostly on the species being processed, but also on the condition of the fish, type of processing operation, the amount of water used, and the type of treatment prior to release. Many reports are available on the characterization of the water from various processed species, and several projects are currently underway (1,11,12). A typical analysis of water from a salmon canning operation is shown in Table I.

At the request of the Fisheries Association of British Columbia, in 1967 the Vancouver Laboratory of the Fisheries Research Board of Canada undertook a survey of the existing pollution problems in the B.C. fishing industry in order to recommend to the companies a course of action to meet the upcoming regulations (2).

Table I. An Analysis of Wastewater from a Salmon Cannery

Insoluble Solids	1200 mg/l.
Soluble (non-salt) Solids	1500 mg/l.
Protein (as N x 6.25)	1800 mg/l.
Biochemical Oxygen Demand	2500 mg/l.
Chemical Oxygen Demand	4000 mg/l.
Turbidity	2500 JCU
pH	6.3
Color	Pink

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*Fisheries Research Board of Canada, Vancouver Laboratory, Vancouver, B.C.

SURVEY RESULTS

Biological treatment at the plant site would in most cases be impossible due to the intermittent nature of operation of this industry. Extremely large lagoons would be required to handle the slug loads encountered during start-up of operations, and would have to be aerated, since anaerobic operation would lead to the production of obnoxious odors due to the high level of sulphur-containing compounds present. Moreover, for a salmon cannery to reduce the BOD level of its effluent from 2500 to 50 would require a system capable of operating in excess of 98 percent efficiency.

In many cases it is possible to use municipal sewerage systems, since the organics present are readily degradable. The high flows and organic loading might easily overload or upset small systems. A surcharge can be expected to be applied by the municipality, due to the high levels of suspended solids, free oil and BOD. One report (11)' gives a formula used by many municipalities which predicts that a 200,000 case per year cannery can expect to pay about $75.00 per day surcharge, or roughtly $0.02 per case. This will probably be the cheapest treatment available.

Since the wastewater contains mostly protein and fish oil, by-product recovery was suggested as a logical first step in the operation. The survey showed that the screening used in the industry was most rudimentary, seldom exceeding the use of 1/4 inch mesh trommel screens. Attempts to use finer screens either of the trommel or vibrating types had failed in the past due to the "blinding" action of the raw protein or fish oil. The first objective then, was to determine if types of screens were commercially available that could achieve better solids reduction.

Sedimentation could only be expected to be partially successful since the solids and oil have a specific gravity close to one. The use of chemical treatment for precipitation and flocculation, however, and air flotation for solids and oil removal suggested itself because of the nature of the pollutants. Since most fish processing plants have or are near to equipment for converting waste solids to fish meal (a poultry feed ingredient) and fish oil, the skimmings could be processed for recovery there.

The second objective suggested by the survey report was to investigate this treatment on a bench and pilot-plant scale, and to follow this up with a demonstration plant if warranted.

FLOTATION THEORY

The theory of flotation may be examined in depth by reference to the works of Gaudin (8) and Vrablik (13). Briefly, all types of flotation cells are similar in principle, although they may differ physically. They operate by the release of air as tiny bubbles from an air water solution through the use of a pressure drop, and the use of this air to obtain a rapid flotation of the solids. The main differences in the type of cells are in the amount of water pressurized (i.e., total versus partial flow pressurization), in the manner in which the air is injected into solution, and in the configuration of the flotation cell.

A typical arrangement of equipment for total flow pressurization is shown in **Figure 1.** Water from the collection tank is pressurized by a centrifugal pump and control valve to roughly 3 atmospheres. Air is injected into the pump suction (as shown) or into the retention tank through a sparger, at roughly two percent of the volumetric flow rate. The retention tank allows sufficient time for most of the air to enter solution. As the water pressure drops in passing through the control valve, the air comes out of solution as pin-point bubbles and collects on any interface present. As the air-water-solids mixture enters the flotation cell, the air will cause the solids and oil to rise rapidly to the surface where they may be removed by skimming. Clarified water is removed from the bottom of the cell. A recycle line is ordinarily connected between the flotation cell and the collection tank to automatically adjust for liquid flow variations and to allow second-pass treatment.

CHEMICAL TREATMENT

Certain chemicals have been used extensively with flotation cells to assist in the separating action by precipitation and flocculation. Many combinations were tested by us, including activated alumina, silica gel, ferric chloride, and numerous polyelectrolytes.

Considerable time was spent in investigation of a by-product of the pulp and paper industry. This derivative of lignosulphonic acid has the ability to quantitatively react with proteins under acid conditions, allowing substantially complete removal. Unfortunately, several inherent properties prevented its use with the flotation cell. Primarily, the compound must be added on a direct ratio with the quantity of protein present, a value which is not readily determined. In addition, the resulting floc is very fragile, and hence not easily removed.

Early tests with aluminum sulphate (alum) showed some promise, but the floc was very small, and slow forming. A literature search revealed that a certain level of alkalinity was required in the water before this chemical could act efficiently(7). Since the water used by plants in the Vancouver area is quite soft, jar tests indicated that about 75 mg/l. of sodium hydroxide was required for proper floccing action. This raised the pH of the water to 9.2. Sufficient alum (or mixture of alum and acid) is then added to lower the pH to between 5.0 and 5.5. A curdy floc is formed which floats readily in the presence of air bubbles. The source of alkalinity appeared to be immaterial, as the system worked with sodium hydroxide, ammonia, lime or soda ash.

Eckenfelder (7) explains the action as follows: the alkalinity converts the charge on the surface of colloids, proteins, flesh particles and oil droplets to negative. As alum is added, the cations are attracted by the opposing charges, thus coating the material. Microflocs are thus formed, which retain a positive charge in the acid range because of the absorption of hydrogen ions. Flocculation agglomerates the particles with a hydrous oxide floc. In this phase surface adsorption is also active. Colloids not readily adsorbed are removed by enmeshment in the floc.

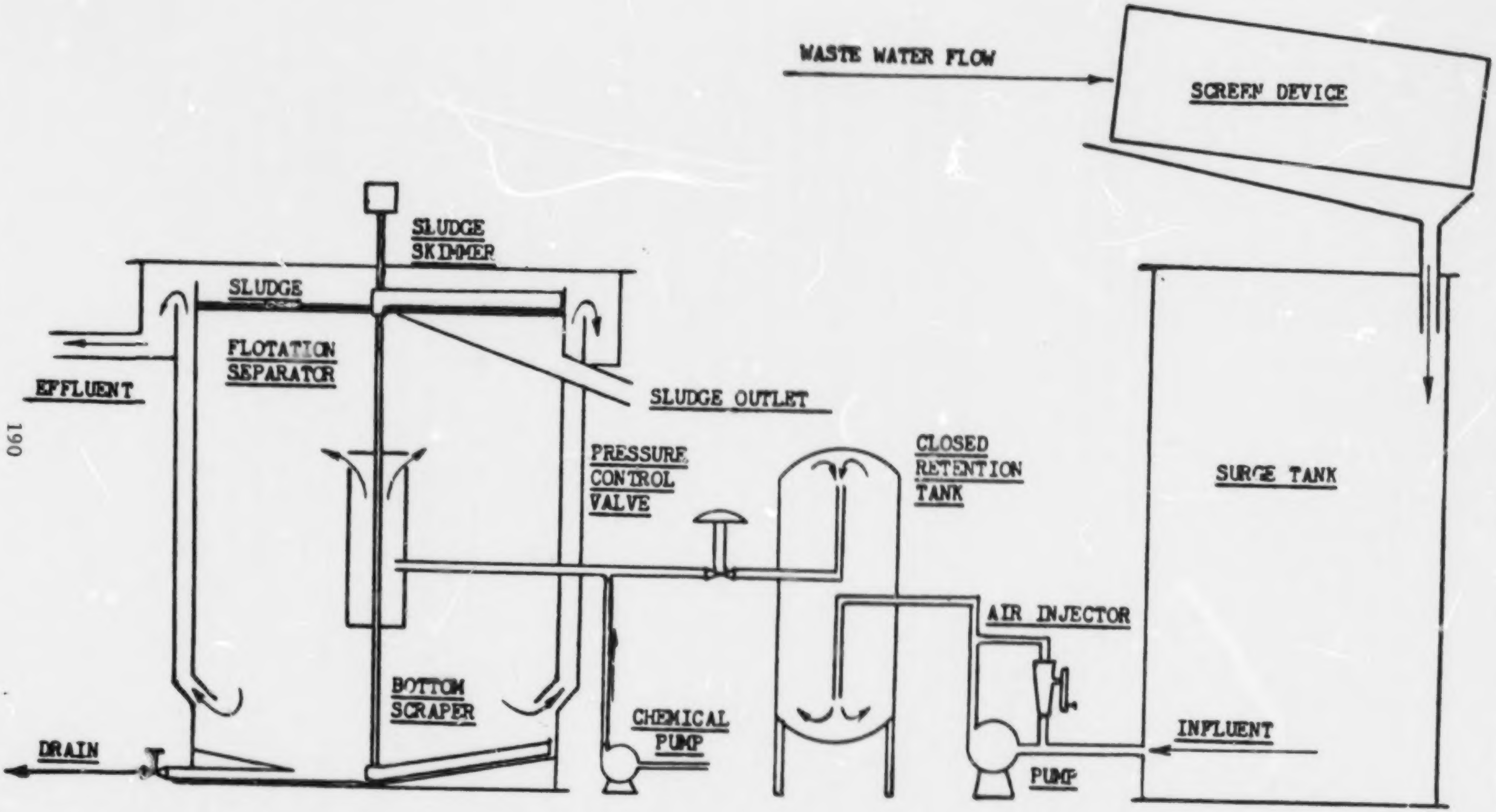
WASTE WATER FLOW
SCREEN DEVICE
SURGE TANK
INFLUENT
PUMP
AIR INJECTOR
CLOSED RETENTION TANK
CHEMICAL PUMP
PRESSURE CONTROL VALVE
SLUDGE OUTLET
SLUDGE SKIMMER
SLUDGE
FLOTATION SEPARATOR
BOTTOM SCRAPER
EFFLUENT
DRAIN

FIGURE 1

AIR FLOTATION

Since the solubility of proteins is decreased as one lowers the pH toward the isoelectric range, (4.0 to 4.7) a lower pH will favour the removal of soluble protein. The optimum pH for floc formation, however, is about 5.2. Anionic polyelectrolytes have been found useful in extending the range over which the floc may be formed, and in increasing the rate of floc formation.

PILOT PLANT STUDIES

The pilot plant programme was funded for two years by a grant made to the Fisheries Association of B.C. by the Industrial Development Service, Department of the Environment. The design of the programme for the first year was made primarily to familiarize ourselves with air flotation and to investigate the problems of operations of this type. A comprehensive description of this test is given in the Vancouver Laboratory Circular 38 (3). The equipment layout was similar to that in **Figure 1.** The unit chosen was a 50 GPM Pacific Flotator, supplied by a division of the Carborundum Corporation.

The equipment was installed at the Paramount Cannery of Nelson Brothers Fisheries, Steveston, B.C. Piping was arranged to take approximately one-tenth of the total waste flow at a point following screening by a 1/4 inch trommel.

A number of problems were encountered in the first year which had to be overcome for the next year's test. The slow floc formation was the chief one, which, as explained earlier, was overcome by the addition of alkalinity. The coarse screening supplied allowed large solids particles to settle in the collection tank and flotation cell, and to plug the aspirator for air injection. This pointed up the need for better screening. Attempting to control the chemical addition by pH measurement looked promising, despite the tendency of the reference electrode to plug with fish oil or fine solids.

By reviewing the results of the first year's work, we were able to make considerable changes in the layout of equipment for the second year. The flotation pilot plant obtained for the second season was a 50 GPM "Favair" unit supplied by Permutit of Canada. This allowed us to contrast the operation of a rectangular cell with a circular one, and to view the operation where air is injected by compressor rather than by aspirator. In our opinion, there was little to choose between the two units. The plant layout for the second year is shown in Figure 2, and a full description of the test is given in FRB Laboratory Circular 42. (4).

Two types of screens were tested for fine solids removal. The North Sewerage Screen (supplied by Green Bay Foundries, Green Bay, Wisconsin) is a submerged rotary screen panelled in this case with a 34 mesh stainless steel screen. See Figure 3. The unit tested was a 4-foot model, rated at 100 GPM.

The other screen tested was of the tangential type, a 1-foot cross-section model DSM screen (supplied by Dorr-Oliver Company). Screen meshes of 20 and 40 were tested. The operating principles are shown in Figure 4.

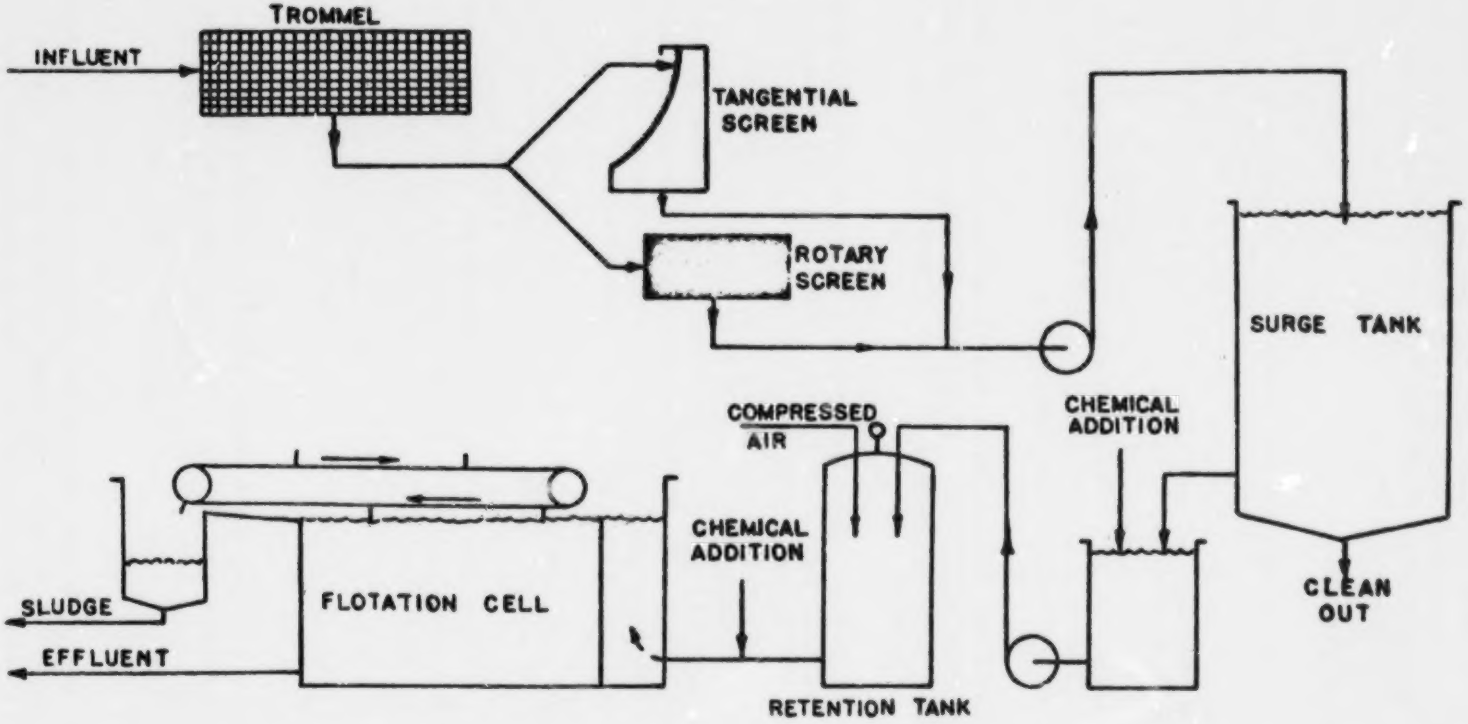
TROMMEL
INFLUENT
TANGENTIAL SCREEN
ROTARY SCREEN
SURGE TANK
CLEAN OUT
CHEMICAL ADDITION
COMPRESSED AIR
CHEMICAL ADDITION
RETENTION TANK
FLOTATION CELL
SLUDGE
EFFLUENT

FIGURE 2 PILOT PLANT LAYOUT

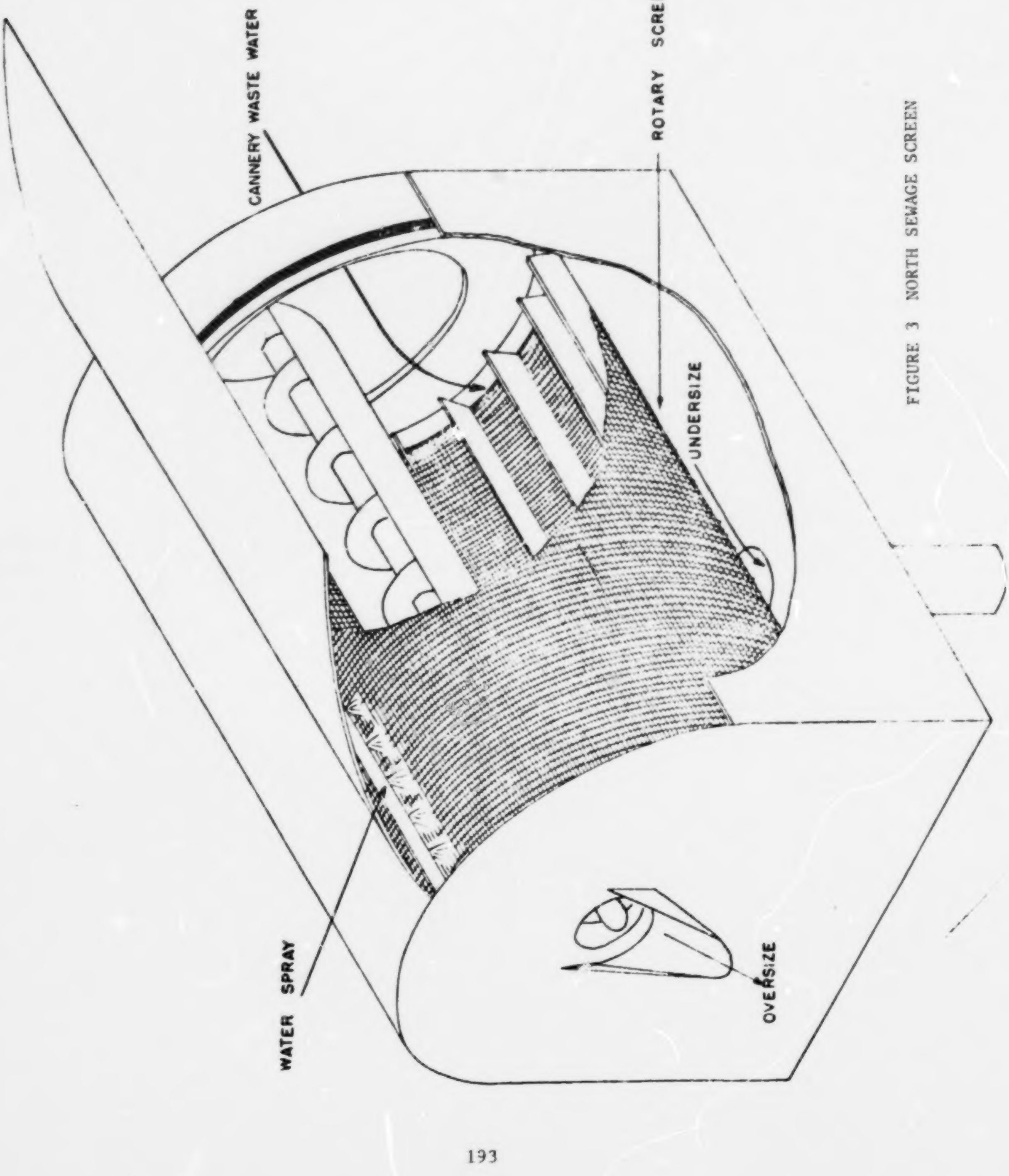
CANNERY WASTE WATER
ROTARY SCREEN
UNDERSIZE
WATER SPRAY
OVERSIZE

FIGURE 3 NORTH SEWAGE SCREEN

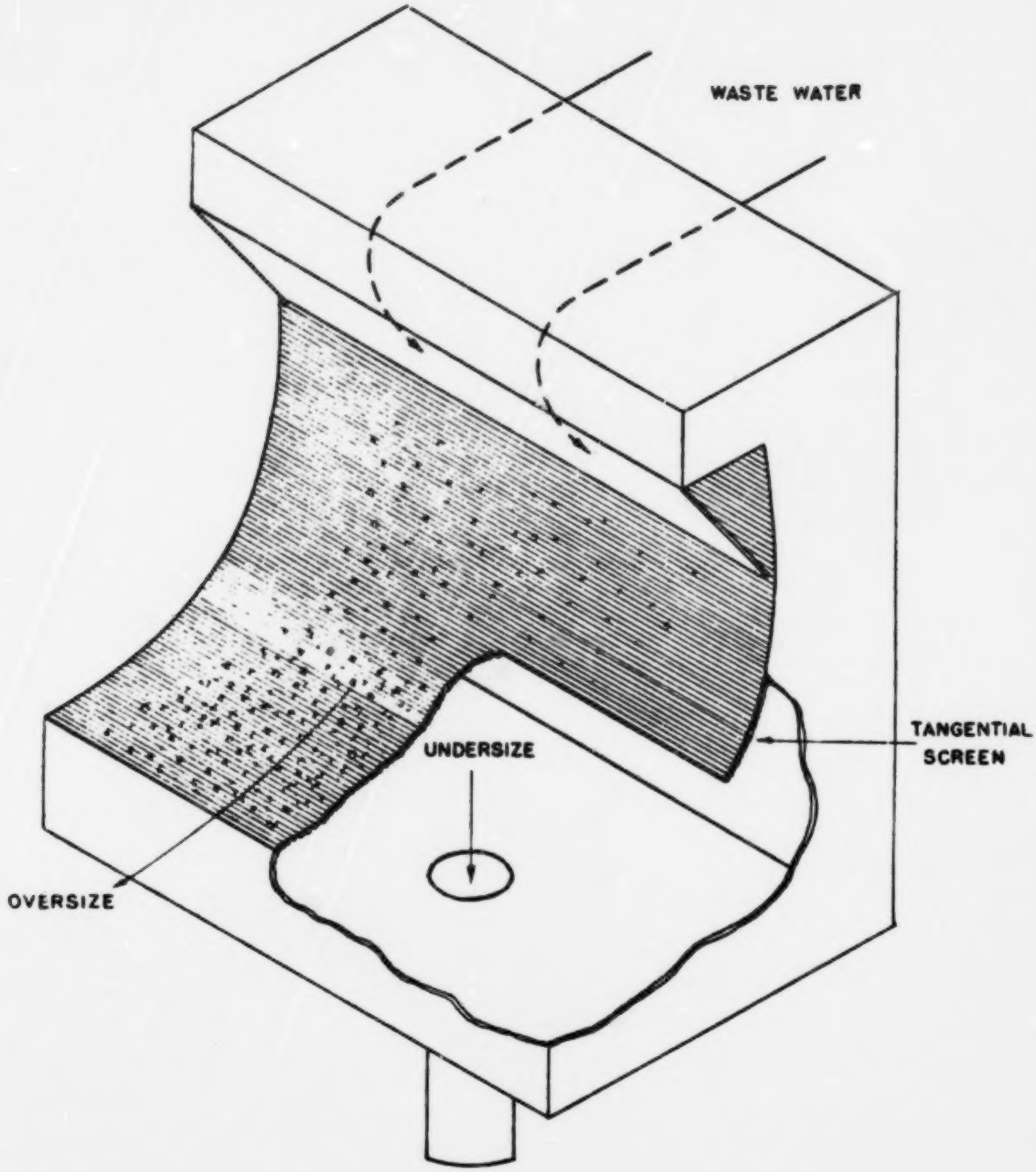
WASTE WATER
TANGENTIAL SCREEN
UNDERSIZE
OVERSIZE

FIGURE DSM TANGENTIAL SCREEN

Both the tangential and rotary screens worked well on salmon-canning wastewater. Operating results are shown in Table II. Some gradual loss in capacity occurred with time with both screens, but this was readily corrected by the use of water sprays.

Table II. Solids Removal from Salmon Canning Wastewater by Screening

DSM Screen 40 Mesh	Total Solids (G/L)	North Screen 34 Mesh	Total Solids (G/L)
Feed	4.5	Feed	4.2
Undersize	2.5	Undersize	2.4
Oversize	164.0	Oversize	105.1

Table III. Solids Removal from Herring Pump Water by Screening

Stream	Tangential Screen Total Solids (G/L)	North Screen Total Solids (G/L)
Feed	6.91	7.36
Undersize	4.58	3.56
Oversize	143.06	111.04

Several herring vessels were unloaded during the season and the pump-out water passed through the screens and flotation cell. The screens worked without too much difficulty although the DSM screen exhibited problems with the scales. The suppliers suggested that a rapping device might correct this situation. The rotary screen operated with reduced capacity, but showed no tendency for the capacity to drop beyond about 75 GPM because of the washing of the submerged surface.

The caustic-alum treatment provided clarification with little floc carry-over, even at rates exceeding the nominal capacity of the unit. The dosage rates averaged 375 mg/l of alum and 75 mg/l of sodium hydroxide. A summary of the results can be seen in Table IV.

The overflow sludge averaged 4.5 percent of the total flow, with an analysis averaging 4.0 mg/l insoluble solids and 0.4 mg/l soluble solids. The data obtained on the solids recovered from the sludge by heating, centrifuging and drying are given in Table V. A sample of this recovered solids was submitted to the University of British Columbia

Table IV. Flotation with Caustic-Alum

Stream	Insoluble Solids (mg/l)		Soluble Solids (mg/l)		Protein (mg/l)		BOD (mg/l)	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Influent	640	250	2045	675	1440	395	1775	915
Effluent	180	70	1305	505	485	240	475	315
% Removal	70	12	38	17	65	18	73	23

1. $\bar{x}$ is the mean, s is the standard deviation.
2. The data are the result of 8 test runs.

Poultry Science Department for evaluation as a supplement in chick starting rations. The meal was included at 2.5, 5.0 and 15.8 percent of the ration, and substituted isonitrogenously for herring meal plus glucose in the control diet. Because of the possible adverse effect of alum, diets containing this ingredient at levels of 0.5 and 1.0 percent were included in the experiment.

The resulting data show that, in a diet in which herring meal is the source of supplementary protein, up to 5 percent of the sample could be included without adverse effects. When the sample was tested as a total replacement, there was a marked reduction in both growth rate and food utilization. The inclusion of alum in the diet at up to the 1 percent level had no significant effect.

Limited tests of the flotation cell herring pump water indicated that results similar to those obtained from treatment of salmon canning wastewater can be expected.

Table V. Analysis of Solids Recovered from the Sludge

Protein (N x 6.25)	50.5%
Ash	10.9%
Moisture	7.7%
Fat	16.5%
Aluminium	0.5%

Note: The data totals only 85.6%, the balance being water of hydration held by the alum.

DEMONSTRATION UNIT

At the conclusion of our pilot plant studies a further grant was made to the Fisheries Association of B.C. to install a demonstration wastewater treatment unit. This was installed in the spring of 1971 at the imperial plant of B.C. Packers Ltd., Steveston, B.C. We designed it to handle the total water flow from their cannery, a total of some 650 GPM. The design details are given in FRB Technical Report 197 (5). Basically, the unit consists of coarse screening, then fine screening through 6-foot DSM tangential screens of .7 mm. The oversize solids are settled in a small tank prior to mixing with the fish plant wastes. The screened liquid is pumped to a 60,000 gallon buffer tank, from where it is withdrawn by gravity flow to a model 1250 Pacific Flotator (supplied by Carborundum Corporation). The wet well for the pumps also acts as a caustic treatment tank for pH adjustment to 9.2. The use of the solid reference electrodes (Lazaran) in our pH indicating system has effectively eliminated problems encountered previously. After pressurization and air addition, alum is added to the water under pH indication to adjust the pH to 5.2. Provisions have been made to add a polyelectrolyte for test purposes. Sludge is skimmed from the tank top and pumped to the reduction plant for protein and oil recovery. The clarified liquid requires pH adjustment to 6.0 prior to release.

A summary of the results obtained during the first season's operation is given in the FRB Technical Report 286 (6). These are given briefly in Tables VI and VII. Since the sludge recovery procedure is being re-evaluated at present, analysis of the operating costs can only include costs to the point of sludge separation. This is estimated at $0.26 per thousand gallons, including the cost of a full-time operator. The data can be extended to show that the value of the recovered solids is about $1.12 per thousand gallons. On this basis, the value of the recovered solids should offset the sum of the unit operating and sludge recovery costs.

Table VI. Operating Data on DSM Screens

Influent insoluble solids = 1650 ± 290 mg/l
Effluent insoluble solids = 960 ± 185 mg/l
Oversize solids content = 13%
Solid recovery = 200 lb/hr

Table VII. Operating Data on Flotation Cell

Stream	Insoluble Solids (mg/l)	Soluble Solids (mg/l)	Protein (mg/l)	COD (mg/l)	Oil (mg/l)	Turbidity JCU
Influent	959 ± 360	1590 ± 245	1545 ± 440	5635 ± 2498	360	2500
Effluent	61 ± 28	1075 ± 155	567 ± 135	815 ± 125	20	200
Removal (%)	92 ± 5	28 ± 16	61 ± 17	84 ± 6		

Sludge volume flow is 2 to 3% of cell flow rate.
Sludge average dry solids is 7.2 ± 2.6%.

Chemical consumption

Sodium hydroxide = 85 mg/l
Alum = 235 mg/l

THE FUTURE

We are planning to operate the unit for another year to obtain firm operating costs, at which time a full report will be made available to all interested parties. We are also planning to extend our investigations to the biological treatment of the clarified water, and the possible use of reverse osmosis. We will endeavour, wherever possible, to extend cooperation to those interested in using this system for any type of food processing wastewater treatment.

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TERTIARY TREATMENT OF COMBINED DOMESTIC AND INDUSTRIAL WASTES

by

Harold W. Thompson* and Kenneth A. Dostal*

INTRODUCTION

This paper is a status report on the Environmental Protection Agency's (EPA) Research and Demonstration Grant No. 11060 DLF. This grant was awarded to the City of Tualatin, Oregon in 1968; and provided funds for the construction and evaluation of a full-scale tertiary system treating combined domestic and industrial liquid wastes.

The data presented herein are based on an initial evaluation of the raw data collected by the grantee between August 1970 and November 1971. A final report covering all aspects of the grant will be prepared by the grantee's technical consultant. The final report should be available for public dissemination during the fall of 1972.

GRANT'S OBJECTIVES

The general objective of the grant was to develop operating and design criteria for a chemical-physical tertiary waste treatment system. Operation of this system was to demonstrate phosphorus removal from the effluent of an extended aeration waste treatment system.

Specific objectives of the grant were to:

1. Demonstrate the biochemical oxygen demand (BOD), suspended solids (SS), and phosphorus (P) removal capabilities at a full scale automated chemical-physical tertiary treatment system treating a combined domestic and industrial waste.
2. Demonstrate the applicability of this tertiary treatment system as an effluent upgrading process for existing activated sludge plants and modifications thereof.
3. Demonstrate the use of tube-type clarifiers for use with extended aeration systems as a substitute for conventional clarifiers.
4. Determine the operational and disposal problems associated with the chemical and biological sludges.

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*Sanitary Engineer and Chief, Food Waste Research Section, respectively, National Waste Treatment Research Program, National Environmental Research Center, U.S. Environmental Protection Agency, 200 S.W. 35th Street, Corvallis, Oregon 97330.

5. Develop design and operating criteria on this treatment system.

6. Determine the economics of the chemical-physical tertiary system.

PLANT DESIGN

Prior to 1968, Tualatin did not have a municipal sewage collection or treatment facility. It was established by the City of Tualatin that the treatment facility be designed to treat the liquid wastes from: the City of Tualatin, two major planned residental subdivisions, a future trailer park, a pet food processing plant, and several existing light industrial establishments.

The plant constructed to treat the waste from the above sources consists of an extended aeration biological unit followed by a package chemical-physical tertiary system. Figure 1 is a schematic diagram of Tualatin's waste treatment system (WTS).

Alum was added to the extended aeration effluent (see Figure 1) in the form of $Al_2(SO_4)_3 \cdot 14\ H_2O$ to enhance removal of SS and P. An anionic polyelectrolyte (Cyanamide 836A) was evaluated as both a coagulant and filter aid.

The unit operations and processes contained within Tualatin's WTS along with specific design features are listed below. Design loadings and/or volumes of the unit operations are tabulated in Table 1.

1. Comminution

2. Extended aeration with:

    a. Floating mechanical aerators
    b. Aeration basin lined with polyvinyl chloride sheet
    c. Aeration basin designed to be utilized as a flow equalization basin
    d. Discharge from basin controlled by a pneumatically actuated discharge pump

3. Tube-type clarifier located within the aeration basin

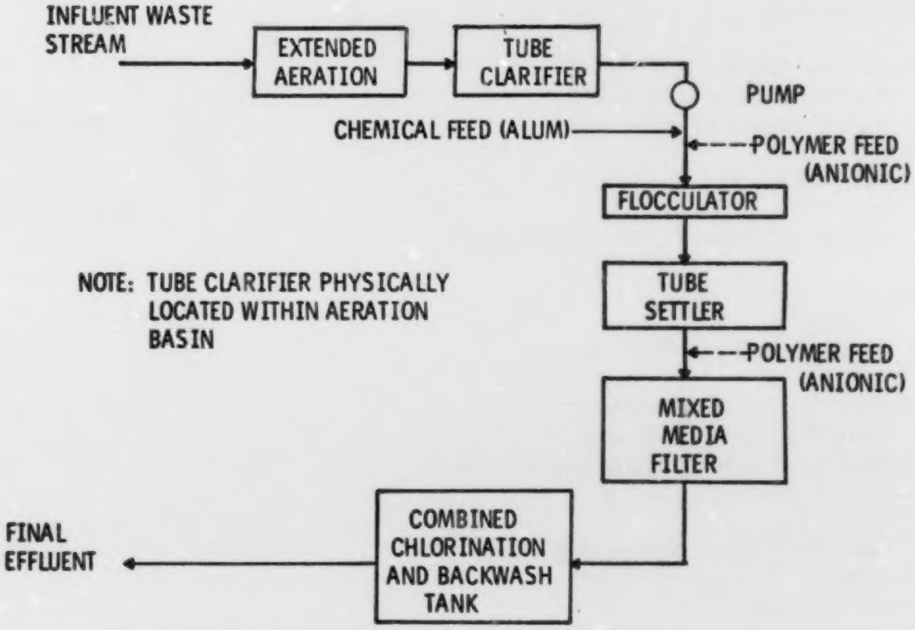
4. Constant head flow splitter box designed to allow any selected constant flow rate to be fed to the tertiary system

5. Flocculator

6. Tube-type solids separator

7. Mixed media gravity filter

8. Combination backwash storage and chlorine contact tank



INFLUENT WASTE STREAM
EXTENDED AERATION
TUBE CLARIFIER
PUMP
CHEMICAL FEED (ALUM)
POLYMER FEED (ANIONIC)
FLOCCULATOR
NOTE: TUBE CLARIFIER PHYSICALLY LOCATED WITHIN AERATION BASIN
TUBE SETTLER
POLYMER FEED (ANIONIC)
MIXED MEDIA FILTER
FINAL EFFLUENT
COMBINED CHLORINATION AND BACKWASH TANK

FIGURE 1 - FLOW DIAGRAM, TUALATIN'S M&I WASTE TREATMENT PLANT

Table 1. Design Data on Tualatin's M&I Waste Treatment Plant

Average Design Flow	280,000 gpd
BOD Loading	700 lbs/day
Aeration Basin	
Floating Aerators (2)	15 Hp (ea.)
Basin Capacity (Max-Min)	280,000-210,000 gals.
Tube Clarifier	
Overflow Rate	2 gpm/ft^2 or 2880 gpd/ft^2
Angle of Tubes (from horizontal)	60°
Flocculator	
Volume	3500 gals.
Detention Time @235 gpm	15 min.
Tube Type Solid Separator	
Overflow Rate @235 gpm	1.7 gpm/ft^2
Angle of tubes (from horizontal)	7.5°
Chemical Sludge Decant Tank Cap.	10,000 gals.
Backwash Storage Tank Cap.	10,000 gals.
Alum Storage Tank Cap.	4,000 gals.
Polyelectrolyte Mixing Tank	750 gals.
Polyelectrolyte Feed Tank	750 gals.
Chemical Sludge Dewatering Ponds (2)	300,000 gals. (ea.)
Excess Activated Sludge Dewatering Ponds (2)	56,000 gals. (ea.)
Mixed-Media Filter (Gravity Filter)	
Depth of Filter	30 In.
Composition of Filter	17" Coal, 9" Silica, & 4" Garnet
Hydraulic Loading @235 gpm	4.8 gpm/ft^2

9. Chemical sludge decant tank with:

    a. Supernatant from decant tank pumped either to the aeration basin or to chemical sludge storage lagoons

    b. Decanted sludge pumped to sludge storage lagoons

10. Chemical sludge and excess activated sludge dewatering ponds with overflow from the ponds being returned to the aeration basin

11. Chemical storage tank

12. Polymer mixing and storage tanks

PLANT OPERATING PROBLEMS

Upon initiating Tualatin's waste treatment system the normal shakedown of operating, equipment and design problems began. The major problems, along with their solutions, that occurred during the evaluation phase of the grant are discussed in the following paragraphs.

The first major problem occurred when gas collected under the PVC liner and caused the liner to float in the aeration basin. The liner was reinstalled according to design; however, after a few days of operation the liner again appeared at the surface of the lagoon. Prior to installing the liner for the third time a gas collection system, vented to the atmosphere, was installed under the PVC and to this date no further liner problems have been experienced.

After a month of continuous operation the SS removal efficiency of the tube-type clarifier decreased rapidly. Effluent SS concentrations of 100-300 mg/l were not uncommon. SS concentration of this magnitude had an adverse effect on the length of filter runs. Upon inspection of the tube clarifier it was apparent that the solids within the unit were being buoyed to the surface by gas bubbles. At one point the entire tube pack floated to the surface. Based on these observations it was concluded that the solids were being concentrated within the tubes for extended periods of time. This condition accompanied by a highly nitrified mixed liquor resulted in denitrification which resulted in solids being transported to the surface by bubbles of nitrogen gas. The equipment supplier developed an intermittent air sparging system for breaking up the solids within the tubes and thus allowing the solids to slough from the tubes. This sparging system has markedly improved the solids removal efficiency of this clarifier. It is now standard daily operating procedure to shut off the secondary effluent pump for approximately 40 minutes each morning. During this 40 minute period the air sparger is turned on for 20 minutes which breaks up the solids contained within the tube clarifier. The air sparger is then turned off and during the remaining 20 minutes the solids are allowed to settle from the tubes.

The flocculator was sized to provide a theoretical detention time of 15 minutes at a design flow rate of 235 gpm. Upon operation of the unit poor floc formation was noted. A study was conducted in an attempt to determine the cause. This study indicated that the actual detention time was approximately eight minutes. In addition, it was noted that air bubbles were being entrapped in the feed stream to the flocculator at the flow splitter box which is located immediately upstream of the flocculator. The following two modifications were made in an attempt to increase the actual detention time and thus improve floc formation. First a plywood diffuser plate was placed in the middle of the flocculator. Holes were drilled in the plate and the plate was installed perpendicular to the vertical axis of the flocculator. The surface area of the diffuser plate approached that of the flocculator. Entrained air was eliminated from the flocculator by insuring that the discharge pipe from the flow splitter box to the flocculator was always submerged. This was accomplished by placing an orifice plate over this discharge port. These two modifications increased the actual detention time to approximately 12 minutes. These modifications did assist in floc formation.

Following flocculation the waste stream flows by gravity to the tube-type solids separator. While operating this tertiary equipment it appeared that the chemical floc was being destroyed by the entrance conditions into the solids separator. The original entrance conditions consisted of a straight discharge from a pipe into a vertical headwall which was located about one foot from the discharge end of the pipe. To modify this flow condition the influent stream into the solids separator was redirected downward and parallel to the headwall by placing a ninety degree elbow on the discharge end of the influent pipe. This change in entrance configuration has assisted in maintaining floc structure.

It was further noted that there appeared to be an incomplete utilization of the solids storage capacity of the tertiary tube-type solids separator. The portion of the tubes located near the inlet to the solid separator would become full of solids earlier than those tubes located farther away. As a result, discharge of solids from some tubes occurred before an appreciable portion of the tube separator's solids storage capacity had been utilized. This inefficient use of the solids storage capacity had an adverse effect on the length of filter runs. No modification or testing of the Tualatin solids separator was undertaken. However, the equipment supplier did perform dye studies on similar equipment and results confirmed the inefficient use of the solids storage capacity. Modification by placing baffles underneath the tubes provided for more efficient use of the separator.

SAMPLING AND ANALYTICAL PROGRAM

Sampling stations, chemical and physical analysis, and the testing schedule utilized during the evalution phase of the grant are shown in Table 2.

Table 2. Sampling and Testing Schedule

Dry Weather Period (Months of August 1970 - November 1970 Inclusive)
(Months of May 1971 - October 1971 Inclusive)

	BOD_5								Nitrogen					
	Total	Dis.	Set. S	SS	DO	Alk.	pH	°C	Total	NO_3	Phosphorous (Ortho & Total)	Cl_2 Demand (Break Pt)	MPN	SVI
Plant influent	12*	--	20	12	-	4	20	20	12	--	12	-	-	-
Secondary effluent	12	--	20	12	-	4	12	--	12	12	12	8	-	-
Tertiary effluent	12	12	20	12	8	4	20	20	12	12	12	8	4	-
Aeration basin contents	2	--	--	8	8	-	20	20	--	--	--	-	-	8
Sludge pond supernatant	2	--	--	2	-	-	2	--	2	2	2	-	-	-

Table 2. Sampling and Testing Schedule (Cont'd)

Wet Weather Period (Months of December 1970 - April 1971 Inclusive)

	BOD_5								Nitrogen		Phosphorous	Cl_2 Demand		
	Total	Dis.	Set. S	SS	DO	Alk.	pH	°C	Total	NO_3	(Ortho & Total)	(Break Pt)	MPN	SVI
Plant influent	12	--	20	12	-	4	20	20	4	-	4	-	-	-
Secondary effluent	12	--	20	12	-	4	12	--	4	4	4	-	-	-
Tertiary effluent	12	12	20	12	8	4	20	20	4	4	4	-	-	-
Aeration basin contents	2	--	--	8	8	-	20	20	-	-	-	-	-	8
Sludge pond supernatant	2	--	--	2	-	-	2	--	-	-	-	-	-	-

* Numbers refer to number of tests scheduled per month.

All chemical analyses, with the exception of dissolved oxygen, were determined on composite samples. Measured physical water quality parameters were evaluated on grab samples. Chemical and physical analyses were analyzed according to "Standard Methods for the Examination of Water and Wastewater," 12th Edition.

Composite samples were collected manually during an eight hour operating shift (8 a.m. - 5 p.m.) and were refrigerated upon collection. These samples consisted of hourly grab samples composited in proportion to the rate of flow.

Other tests and observations conducted during the evaluation phase of the grant were: daily hydraulic effluent volume, hours per day of tertiary operation, velocity profile within the aeration basin, and solids deposition on the bottom of the aeration basin.

PLANT LOADINGS

Tualatin's waste treatment plant was designed for a hydraulic loading of 280,000 gals/day whereas the flow to the plant averaged 97,000 gals/day during the 14 month monitoring period. A geometric frequency distribution of the hydraulic loading observed during this period is illustrated by Figure 2.

Daily BOD_5 loadings ranged from 24 to 1500 lbs with an average of 480 lbs. The design BOD loading, as shown in Table 1, was 700 lbs/day. This design value was exceeded on 20 percent of the samples collected during the monitoring period.

A pet food processing plant was the largest industrial waste source discharged to Tualatin's waste treatment facility. Incremental additions from the processing plant can be estimated from the data in Table 3 and they amounted to approximately 25, 50, and 75 percent of the flow, SS, and BOD_5 respectively, applied to the treatment plant during normal operation.

Table 3. Influence of Pet Food Processing Plant on STP Loadings

	Q (MGD)	SS (mg/l)	BOD_5 (mg/l)
Proc. Plant Closed (2 wks vac.)	.075	340	180
Proc. Plant Operating (2 wks prior & after vac.)	.100	690	750

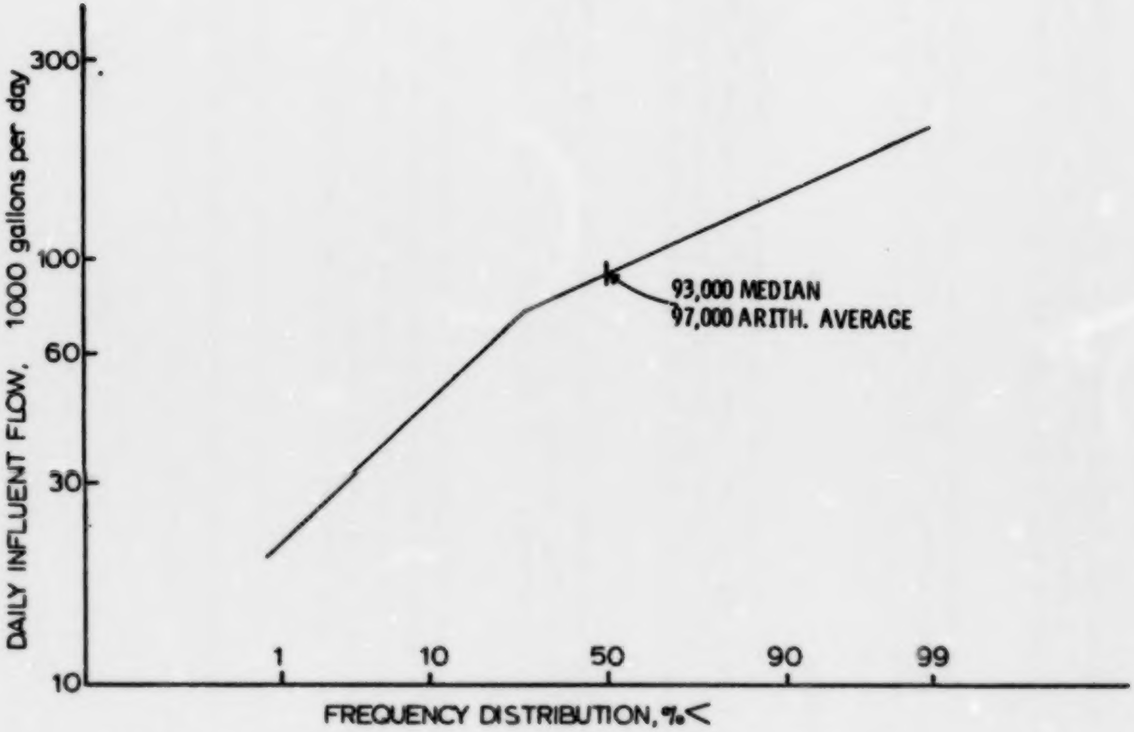


FIGURE 2 - GEOMETRIC FREQUENCY DISTRIBUTION OF DAILY INFLUENT FLOW

PLANT PERFORMANCE

In operating the tertiary chemical-physical system many combinations of flow rate, alum dosages and polyelectrolyte concentrations were evaluated for their effect on SS and P removal. The various levels investigated are shown in Table 4.

Table 4. Tertiary Operating Variables

Flow Rate, GPM	75	110	140	190
Alum Dose, mg/l	0	100	125	155
	180	210	240	
Polyelectrolyte, mg/l				
Pre-settler	0	0.5	1.0	1.5
	2.0			
Pre-filter	0	0.03	0.06	0.1

Frequency distributions of SS (Figure 3) and BOD$_5$ (Figure 4) concentrations indicate the removal capabilities of the treatment facility. It should be understood that the tertiary effluent frequency distributions include all levels of operating variables (flow rate, etc.).

In Figure 3 the secondary effluent frequency distribution has an appreciable change of slope at approximately the 90 mg/l SS level. This break was caused by the higher solids concentration levels discharged from the tube-type clarifier prior to the installation of the air sparger system (as discussed earlier).

Lower BOD$_5$ and SS removal efficiencies were observed through the secondary biological system than would normally be expected. This was primarily caused by the high solids concentrations discharged from the tube-type clarifier.

Overall treatment plant BOD$_5$ and SS removals, influent to tertiary effluent, averaged 98 and 99 percent, respectively, with an average final effluent BOD$_5$ concentration of approximately 8 mg/l and SS level of 6 mg/l.

Figure 5 illustrates the effect that alum dose had on the removal of SS and ortho-P through the tertiary chemical-physical system at a specific flow rate. As is shown in this figure, ortho-P levels of less than 0.1 mg/l were obtained at alum dosages of 240 mg/l. Effluent SS were reduced to 3 mg/l with an alum dose of about 125 mg/l.

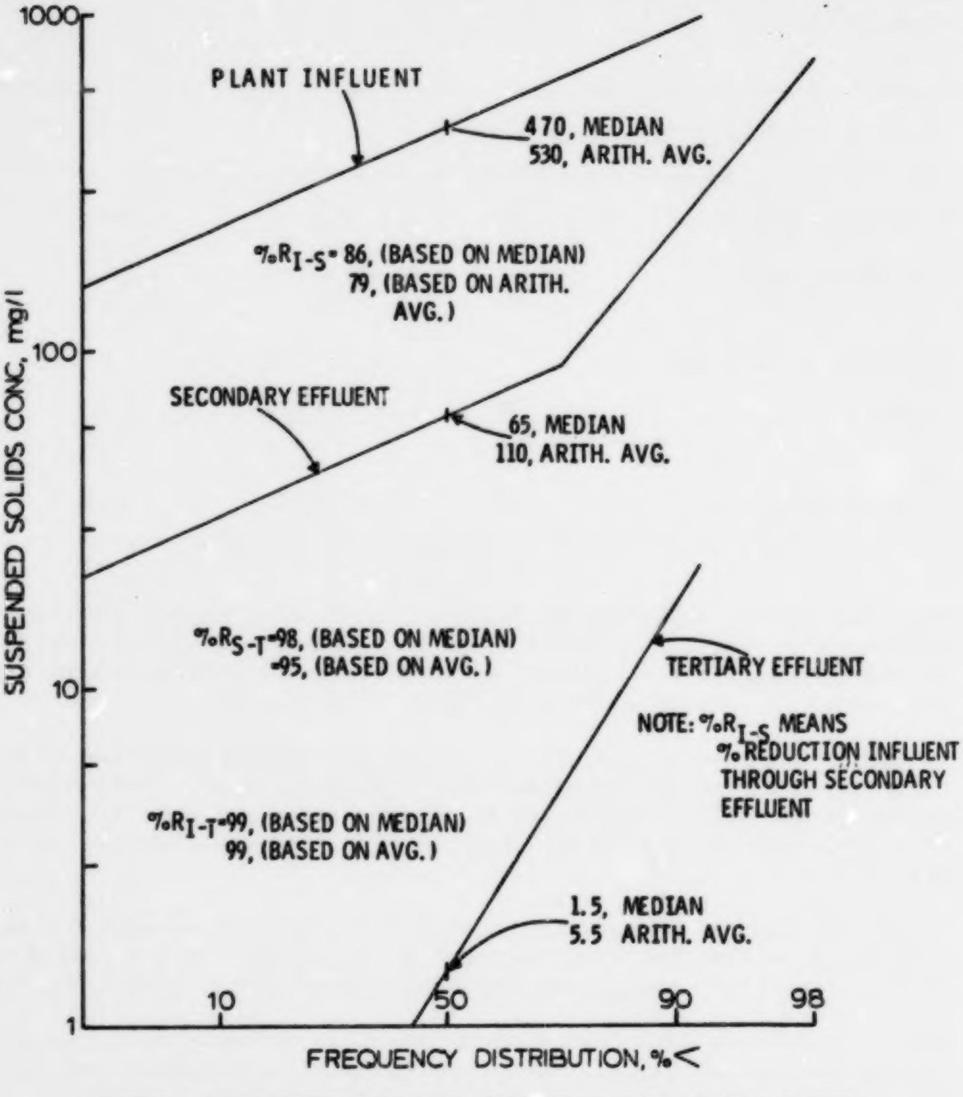


FIGURE 3 - GEOMETRIC FREQUENCY DISTRIBUTION OF SUSPENDED SOLIDS

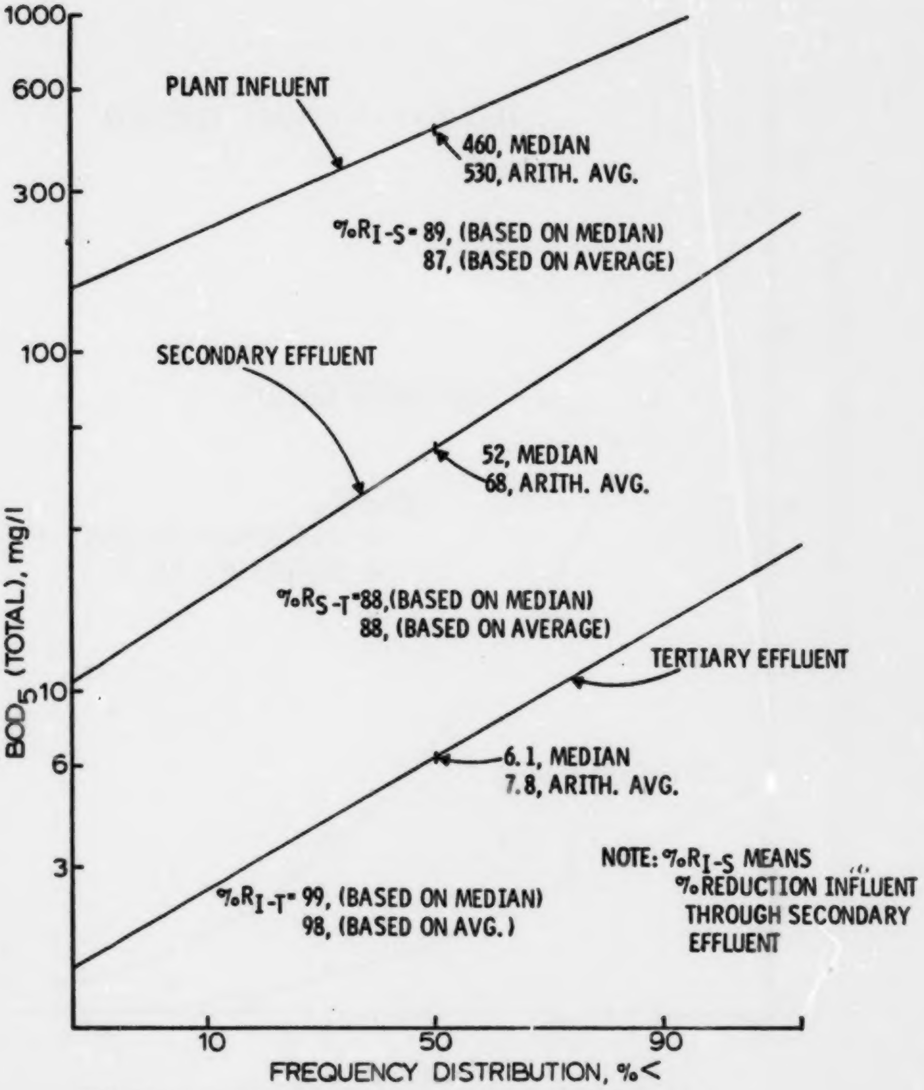


FIGURE 4- GEOMETRIC FREQUENCY DISTRIBUTION OF BOD$_5$

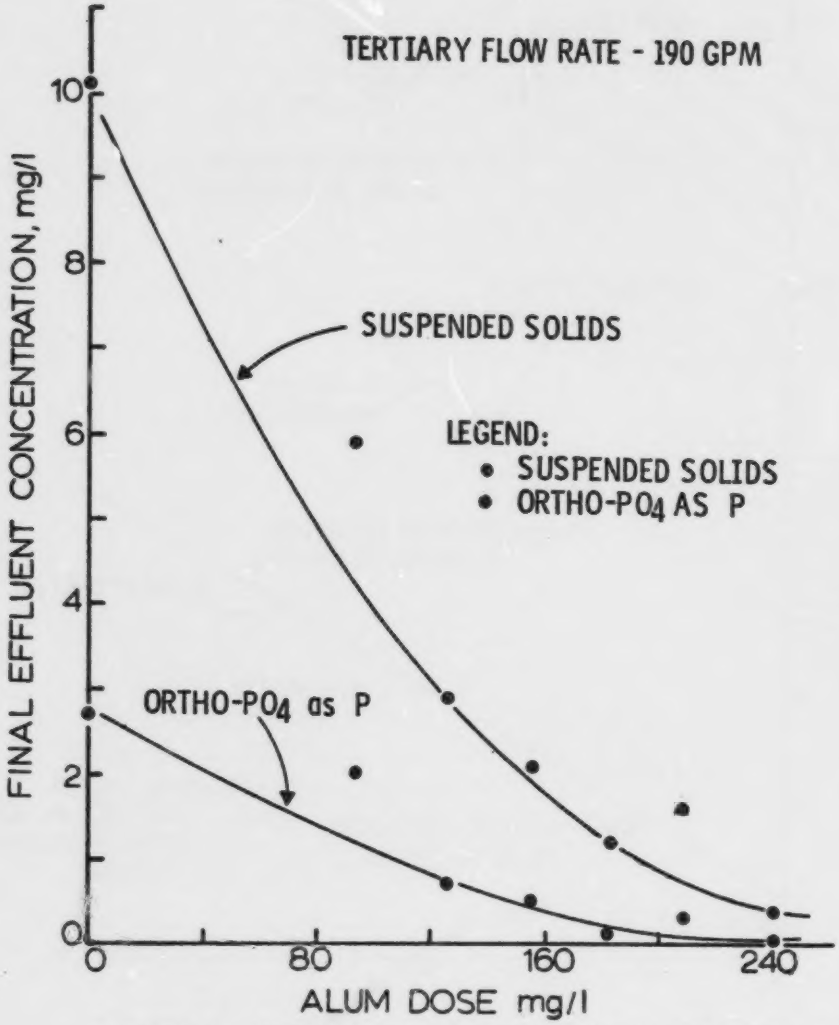


FIGURE 5, EFFECT OF ALUM DOSE ON EFFLUENT SS AND P LEVELS

Table 5 compares the final effluent with and without alum addition. The data presented covers all ranges of flow rates through the tertiary system along with all alum concentration investigated. Alum resulted in a 75, 40, 75, and 75 percent reduction in SS, total BOD_5 and total and ortho-P concentration, respectively, through the chemical-physical system.

Table 5. Tertiary Effluent

	Without Alum (mg/1)	With Alum (mg/1)
Suspended Solids	14.7	3.5
BOD_5, Total	11.6	7.0
BOD_5, Soluble	5.5	4.7
Total PO_4 as P	5.7	1.5
Ortho PO_4 as P	5.3	1.3

SUMMARY

The objective to demonstrate the BOD, SS, and P removal capabilities of a full scale automated chemical-physical tertiary treatment system treating combined domestic and industrial waste was met. In fact, it was shown that under correct operating conditions a high quality effluent could be obtained from Tualatin's WTS.

The tertiary unit was definitely shown to be an excellent method of upgrading effluent from activated sludge plants and modifications thereof. Extremely high percent removal was obtained through the tertiary process even with poor secondary effluent quality. The poor quality secondary effluent appeared to be the result of the poor liquid-solids separation obtained in the tube-type clarifier.

Data pertaining to the grant's other objectives have not been evaluated, as yet. However, upon complete evaluation of all the data collected during the monitoring phase of this grant many of the remaining objectives should be fulfilled. Further data evaluation will be undertaken by the grantee's technical consultant and as stated earlier, the final report on the grant should be available for public dissemination during the fall of 1972.

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OCEAN ASSIMILATION OF FOOD RESIDUALS

by

Walter W. Rose*, Allen M. Katsuyama*, and
Richard W. Sternberg**

INTRODUCTION

In the East Bay there are six food processing plants which rely on a common hauling company to pick up, transport and dispose of solid residuals generated during the processing of fruits and vegetables. Up to ten years ago, these waste residuals were being handled in a sanitary landfill operation. This practice was adequate as long as suitable area and sufficient dry waste in the form of domestic refuse could be mixed with the food residuals.

Two problems hastened the need for the development of an alternate disposal method. First, production by the canneries increased with a resultant increase in solid residuals, thereby causing an imbalance between dry and wet waste at the disposal site. Second, the landfill operation gradually moved to an area of high water table, resulting in seepage of bay water into newly filled cells.

Beginning in 1960, cannery waste primarily from the processing of fruits was centrally collected, loaded on a barge and transported more than 20 miles beyond the Golden Gate for discharge in ocean waters. A total of four monitoring trips were made in 1960 and 1961 to determine the effects of this discharge on the quality of the receiving waters. The results of these trips indicated only a momentary depression of certain water quality parameters.

As a result of increasing awareness of ecological problems, general concern has been recently expressed about the use of marine waters as a depository for waste materials. On November 4 and December 1, 1970, reports and presentations were made before the San Francisco

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*Western Research Laboratory, National Canners Association, Berkeley, California 94710

**Washington Research Laboratory, National Canners Association, Washington D. C.

Bay Region Water Quality Control Board by the State Department of Fish and Game. These reports indicated that the San Francisco Bay Area crab harvest had declined drastically during the past 10 years. Since the crab larvae exist in planktonic forms for about 110 days, during January to June of each year, the State Fish and Game biologist recommended that all industrial waste discharges into the marine environment be prohibited. However, it was stated that food residuals were being discharged only between July and October of each year.

On December 22, 1970, the San Francisco Bay Regional Water Quality Control Board adopted Resolution No. 70-100 which would prohibit the disposal of cannery residuals into the ocean after November 1, 1971, unless it could be demonstrated to the satisfaction of the Board that such wastes would have no adverse effects on water quality. The discharger was required to file by February 15, 1971, an outline for a study into the effects of food processing solid residuals upon water quality and upon protected beneficial uses.

Development of 1971 Study Program

On February 25, 1971, the San Francisco Bay Regional Water Quality Control Board accepted the study outline which was prepared by the National Canners Association on behalf of the Oakland Scavenger Company. A progress report was required by August 15, 1971, and a final report submitted on October 15, 1971.

An outline of the proposed 1971 study is given below and is divided into five sections.

I. Definition and Characterization of Waste
  A. Description of Waste
  B. Characteristics of Waste
    1. pH
    2. suspended solids
    3. volatile solids
    4. settleable solids
      a. rate of settling
    5. percent solids
    6. total oxygen demand
    7. chemical oxygen demand
    8. biochemical oxygen demand
      a. 15 minute immediate oxygen demand
      b. short term oxygen up-take (6 hours)

        - c. 5-day BOD
        - d. 20-day BOD
        - e. ultimate BOD
    - 9. proximate analysis
        - a. protein
        - b. carbohydrate
        - c. crude fibre
        - d. fat
    - 10. agricultural chemical residues
        - a. chlorinated hydrocarbons
        - b. organophosphates
    - 11. 48 hour fish bioassay
    - 12. heavy metals (cadmium, chromium, copper, lead, mercury and zinc)

II. Ocean Monitoring and Sampling
- A. Dispersion Pattern of Waste Field
    - 1. depth (surface, 10 ft, 20 ft, and bottom)
    - 2. width
    - 3. length
    - 4. aerial photograph
- B. Receiving Water
    - 1. pH
    - 2. temperature
    - 3. dissolved oxygen demand
    - 4. total oxygen demand or approved tracer substitute

III. Statement Regarding The Status of By-Product Utilization and Alternate Disposal Methods

IV. Statement Regarding The Pre-Treatment of Solid Residuals With Regard To:
- A. pH control
- B. Biological Treatment
- C. Solids Removal

V. Shoreline Inspection --- if needed

A committee comprised of canners, representatives from State regulatory agencies, the National Canners Association and the Oakland Scavenger Company was formed to implement and revise, if necessary, the proposed 1971 study. Some changes were made in the program and will be mentioned in the text.

CHARACTERIZATION OF SOLID RESIDUALS

Peaches and pears are the two major fruits processed by the East Bay Canneries. On a seasonal basis it is estimated that waste generated from these two commodities constitute about 90% of the total amount of those food residuals which are placed in the ocean waters.

The solid residuals produced from pear processing are composed mainly of peel, core, stem and blossom end cuts. Approximately 80% of the total quantity of pear residuals comes from these operations. The remaining solids consist of chip particles, fruit sorted out as being over ripe or containing defective material unacceptable for canning.

Peach residuals consist mainly of over and under ripe fruit, culls or undersized fruit and normal peaches diverted away from production as a result of a California marketing order. These sources contribute approximately 90% of the total peach waste. The remaining quantity is made up of small particles and fruit removed from sorting belts as being unacceptable for canning.

Analysis of Solid Residuals

A summary of the data collected for the analysis of the solid residuals is contained in Table 1. Data are presented for the minimum and maximum values found in the analysis of four separate samples. The analysis was performed on fresh samples before the addition of dilution water at the reservoir site. Results are expressed on a wet weight basis.

The data collected for the characterization of solid residuals was performed on samples taken on July 30, August 6, August 12, and August 27, 1971. In late June fresh market peaches and pears were purchased and used to develop procedures and analytical techniques. The fresh market fruits were also used in running the first bioassay.

Figure 1 is a plot of the BOD of one solid residual sample with respect to time. The five-day BOD is 69% of the 20-day BOD which indicates the presence of easily oxidizable organic matter. The ratio between the 5-day and 20-day BOD also indicates the absence of any substances of a toxic nature to bacteria.

Table 1. Physical and Chemical Characteristics of Food Processing Solid Residuals

Parameter	Minimum	Maximum
pH	3.6	3.7
Suspended solids, ppm	29,000	35,400
Volatile suspended solids, ppm	15,200	18,600
Settleable solids, ml/L	56	61
Total solids, ppm	176,800	181,800
Chemical oxygen demand, ppm		
Jeris method	185,000	197,500
Standard method	192,000	207,900
Total oxygen demand, ppm		
settled	143,200	152,000
mixed	199,100	213,200
Biochemical oxygen demand, ppm		
15-minute	310	400
6-hour	3,900	4,400
5-day	82,000	88,000
20-day	118,800	128,000
ultimate BOD		
1-day	32,100	36,700
3-day	73,600	77,000
5-day	82,200	88,000
7-day	85,800	91,300
9-day	94,300	99,800
11-day	96,100	101,000
13-day	96,700	104,600
15-day	111,300	117,800
17-day	119,900	124,200
19-day	121,000	125,600
21-day	126,200	133,000
Proximate analysis		
protein, %	0.61	0.814
carbohydrate, %	7.60	8.50
crude fibre, %	3.57	3.97
fat, %	0.16	2.30

Table 1. (cont'd) Physical and Chemical Characteristics of Food Processing Solid Residuals

Parameter		Minimum	Maximum
Agricultural chemical residues, ppm			
chlorinated hydrocarbons		0.010	0.02
organophosphates		0.015	0.03
Heavy metals, ppm			
cadmium		0.04	0.08
chromium	less than	0.02	0.02
copper		0.01	0.04
lead		0.08	0.10
mercury		0.006	0.009
zinc		0.06	0.13

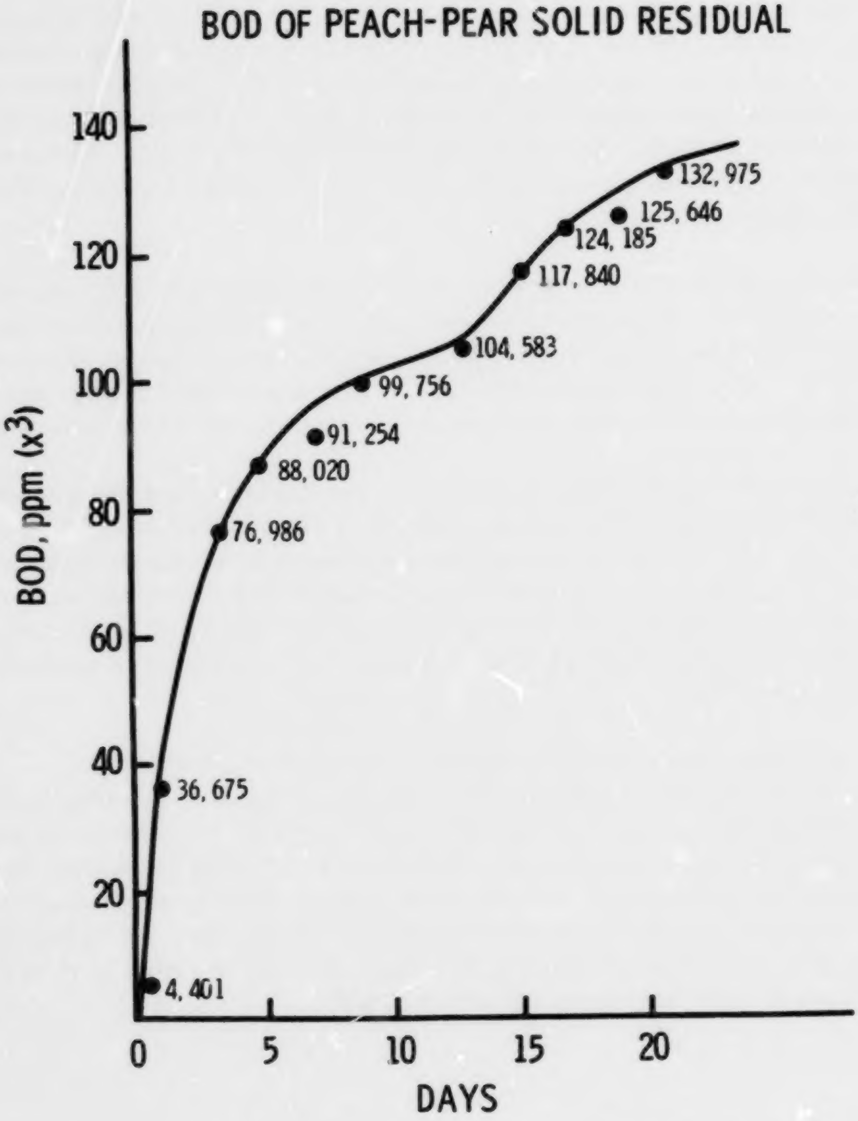

Figure 1. BOD of Peach-Pear Solid Residual

The immediate oxygen demand, as measured by the 15-minute BOD value has a maximum value of 400 ppm. As will be shown later, there is a dilution ratio of one part residual to 542 parts of ocean water which means that the maximum oxygen demand placed on the receiving water is 0.74 ppm. Also, when dilution of the residuals with bay water and sea water is considered, the actual oxygen demand is less than 0.74 ppm.

The analytical values for pesticide residues are very low and less than that being permitted in the final product by the Food and Drug Administration. DDT or its analogues were not detected in any of the samples analyzed. A check with the field departments of the canners verified the fact that growers did not use DDT during the growth of the products. Furthermore, a check of the pesticides used by the growers indicated a definite shift to the use of nonpersistent pesticides.

The pesticide analysis was performed with a Tracor Model 211 gas chromatograph using an electron capture detector. The total concentration of chlorinated pesticides was estimated by summation of the recorded peaks, using aldrin as the reference compound. The organophosphates were determined in a similar manner, using diazinon as the reference compound.

Of the known pesticides applied to the raw products during the growing season, Kelthane was present in the greatest concentration of chlorinated hydrocarbons. It is estimated that the maximum concentration of this material was 0.008 ppm. For the organophosphates, diazinon and parathion appeared in equal concentrations of approximately 0.0075 ppm. Nonpersistent carbamates such as sevin, ziram and maneb were extensively used by the growers.

It was beyond the scope of this project to attempt to identify each of the peaks recorded by the gas chromatography analysis. Those pesticides known to have been applied to the raw product and known to be persistent were looked for on the chromatograms. Some chromatographic peaks, in the chlorinated hydrocarbons and organophosphate analysis, were questionable and were most probably of a nontoxic nature. Therefore, it is reasonable to believe that the values reported in Table 1 are on the high side and that the actual levels are less than those reported.

COLLECTION OF SOLID RESIDUALS

The solid residuals generated at the food processing plants are separated from liquid waste by means of screens. The most commonly used screens are of the flat, vibrating type containing 20 openings to the inch, commonly referred to as 20 mesh screens. The separated solids are held in hoppers until removed by a truck. In most instances, the solids are removed from the hopper within one hour.

Solids from the canneries are hauled to a common site prior to the loading of the barge. Figure 2 is a photograph of the solids being unloaded into the first part of a two sectional reservoir.

Figure 3 is a view of the grinder in the foreground. In the background is a drag conveyor which takes the waste after dumping and feeds it to the grinder.

Figure 4 is an overall view of the reservoir site containing ground fruit waste solids. On standing, even for short periods of time, the ground material separates into two phases. The insoluble materials accumulate on the surface with free liquid below. Before the barge is loaded, city water is pumped into the reservoir; recirculation pumps are turned on to mix the liquid and solid phases.

Figure 5 is an overall view of the pipe from the reservoir connected to the piping system on the barge. The barge is divided into four separate compartments and each compartment contains a pump. A fifth pump on the barge takes in sea water to further dilute the solids once the discharge has begun.

The barge has an overall length of 165 feet, width of 40 feet and draft of 9 feet. When fully loaded it contains a net weight of 1040 tons. The barge is line towed by means of a tug boat which moves at a minimum of 2-1/2 knots. During disposal of the residuals the minimum speed is normally 3 knots.

Dilution of Solids

After an estimated barge load of ground waste has accumulated in the reservoir, city water is added primarily to improve the pumping characteristics of the waste. The water volume is metered; a quantity of water equal to 20 to 25 percent of the reservoir contents of ground waste is added, thereby diluting the waste by a comparable factor.

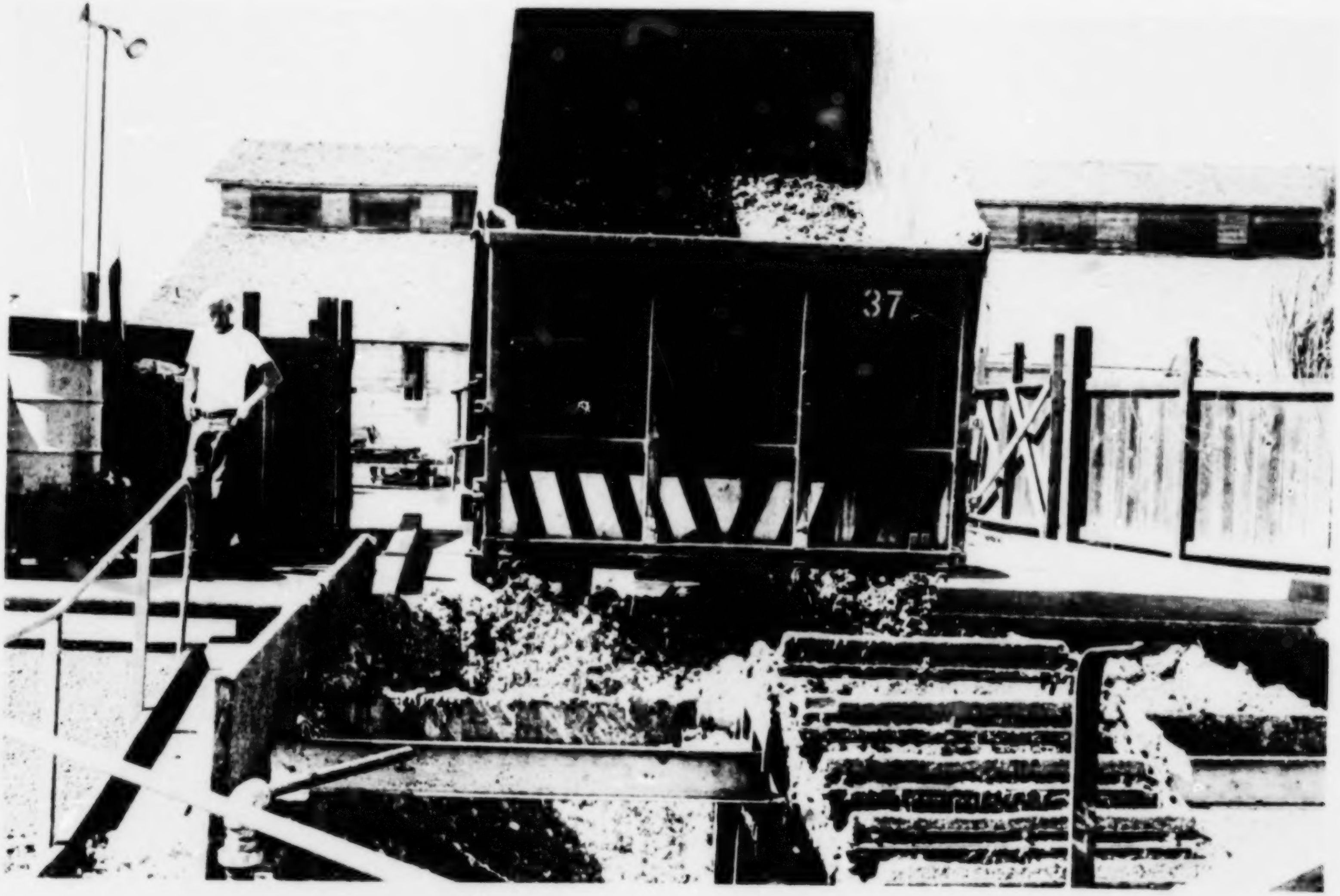

Figure 2. Unloading of Solids at Central Collection Site

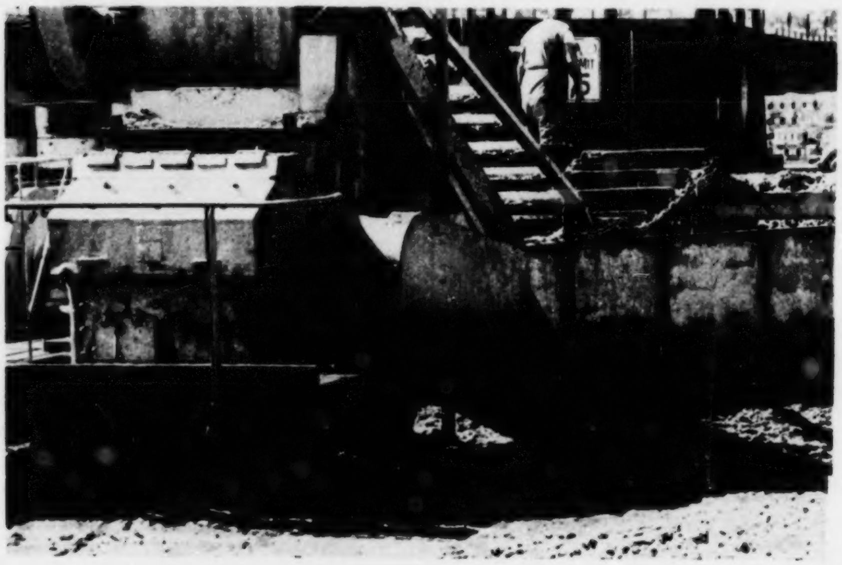

Figure 3. Grinding of Solid Residuals

Figure 4. Overall View of Collection Site

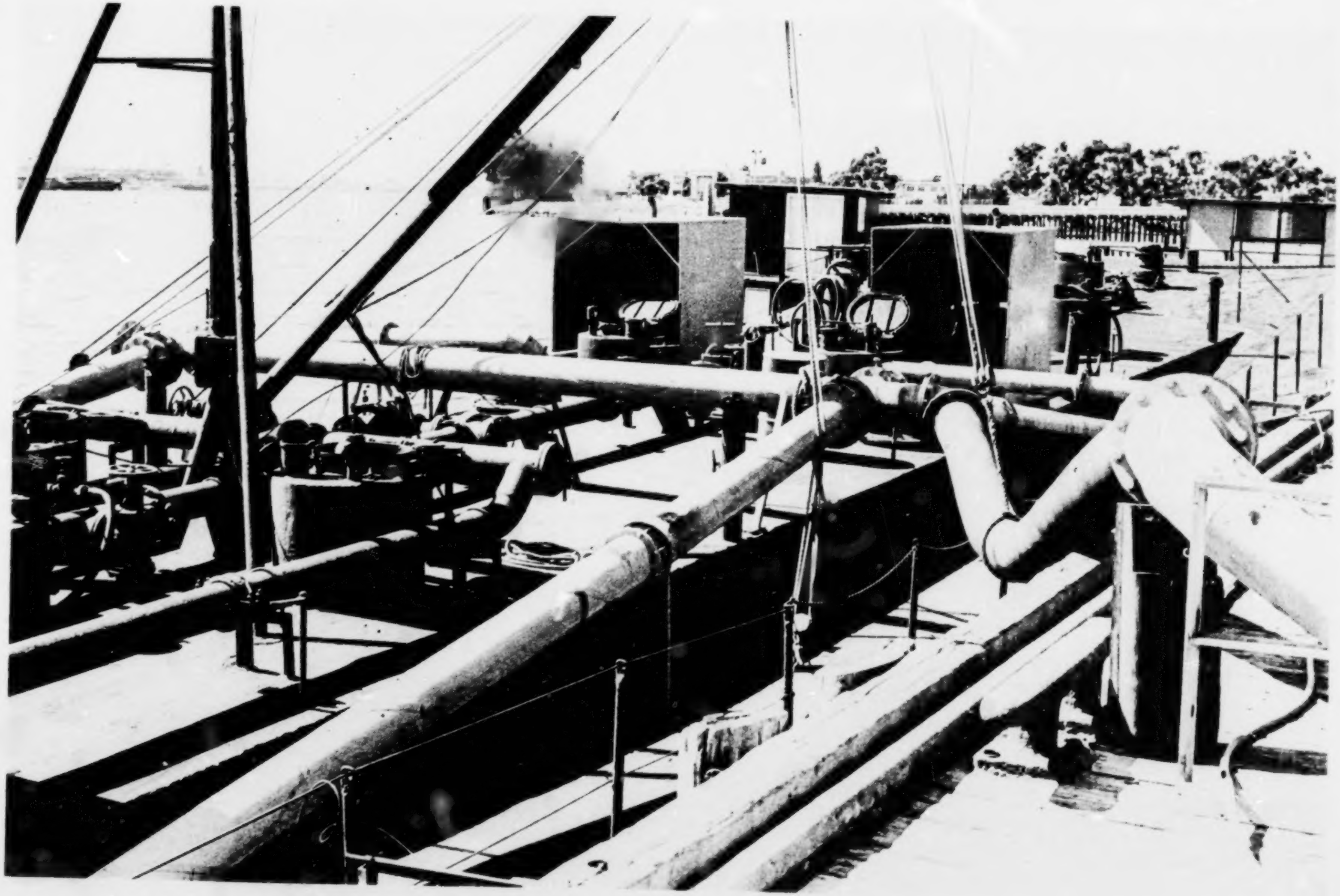

Figure 5. Loading of Barge

Once the barge is in the disposal area and ready for discharge, a pump is started to take in and distribute sea water to the four waste compartments. Thus, when the four compartment pumps are discharging, the waste is diluted by an additional factor of 25 percent. At times during the draw down of the barge, only two pumps are operated, in which case there is a 50 percent dilution during discharge.

As previously indicated, the analysis reported in Table 1 is for waste as delivered to the reservoir site. By considering the dilutions mentioned above, the actual concentrations of substances, at the point of discharge, are generally one half those reported in Table 1.

MONITORING PROGRAM

A total of three monitoring trips were made during 1971. During the first two trips water samples and data were collected before discharge and during discharge at four distances behind the barge and at various depths. On the third trip the monitoring vessel was initially positioned approximately 500 feet behind the barge. While the barge continued its normal course, the monitoring vessel remained in this stationary location and samples were collected from various depths with respect to time. Also on this third trip, samples of floatables were collected with respect to time.

A map of the disposal area and the various boundary lines are depicted in Figure 6. Because food residuals are classified as garbage, it is necessary for the barge to go beyond the 20-mile limit. The discharge area, in addition to being beyond the 20-mile boundary, is also outside the 3-mile State jurisdiction as applied to the Farallon Islands.

Prior to the first monitoring trip, a Rhodamine dye was added at the reservoir site as the food residuals were being ground by the hammermill. Sufficient dye was added to give a concentration of 10 ppm in the barge when fully loaded. However, at the disposal area it was only possible to detect a minimal dye concentration of approximately 2 parts per billion (ppb) at the closest monitoring position (100 feet) behind the barge. This is evidence that there is a high dilution and a rapid dispersion once the material enters the ocean. The above value indicates a 5,000-fold dilution of the material at a point 100 feet behind the barge.

On the third monitoring trip a concentrated dye was used to mark the sampling field. When the sampling vessel was in position, a signal was given and the dye was released from the stern of the barge. In addition to using the dye as a means of marking the field, a floating buoy was thrown overboard to be used as a guide by the monitoring vessel. However, the buoy was useful for only approximately 30 minutes, after which time winds had caused it to drift out of the waste field.

The Marine Ecological Institute provided the vessel for use in the monitoring phase of the 1971 study. Personnel from the Institute were most helpful in reviewing the objectives of the monitoring program and in serving as part of the monitoring team. Planning sessions were held aboard the monitoring vessel during each trip to the disposal area (Figure 7). At this time additional work assignments, as well as an overall review of the objectives of the trip, were made. An average of three hours elapsed from the time of departure until arrival at the disposal site.

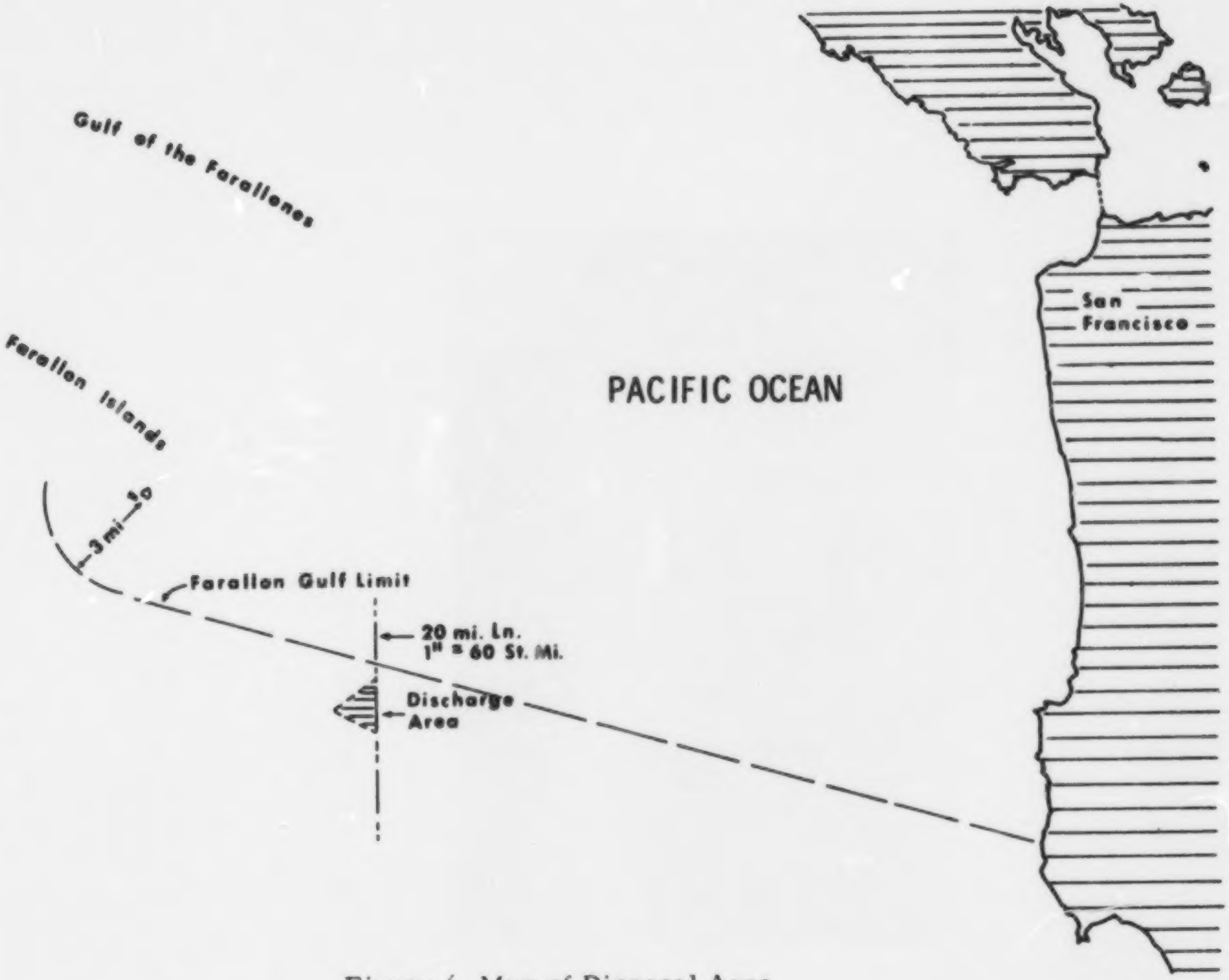
Gulf of the Farallones
Farallon Islands
3 mi
Farallon Gulf Limit
20 mi. Ln.
1" = 60 St. Mi.
Discharge Area
PACIFIC OCEAN
San Francisco

Figure 6 Map of Disposal Area

Figure 7. Planning Session on Monitoring Vessel

Figure 8 shows the reading of the current meter after being in the water for 10 minutes. The readings for velocity and direction of the ocean waters found during the monitoring trips are summarized below:

2.008 knots at 60°
1.090 knots at 40°
1.020 knots at 10°

Figure 9 is a photograph taken of the barge in the disposal area just prior to the beginning of the discharge of solid residuals. The monitoring vessel was manuevered into the correct position behind the barge as discharge was commenced.

Figure 10 is a view directly behind the barge. On either side can be seen the discharge pipes submerged below the water surface. Each pipe extends 5 feet below the surface when the barge is empty. With a fully loaded draft of 9 feet, the pipes are 14 feet below the water surface.

Submerged discharge of the food residuals was first provided in 1971; the previous mode of disposal had been surface discharge. The data and observations collected during 1971 supported the contention that this change significantly improved the disposal operation by providing a greater dilution of the waste within the receiving waters and resulting in less floating material and less water discoloration.

A TDC instrument (Figure 11) was used to collect temperature, depth, and conductivity data. With well-established correlation factors, conductivity readings were readily converted to salinity.

Water samples were collected with Van Dorn bottles. By affixing three bottles to appropriate points on a weighted cable (Figure 12), simultaneous samples were collected from three different depths. Waters from these samplers were transferred into BOD bottles (Figure 13) for dissolved oxygen determinations and to reagent bottles for pH measurements (Figure 14) and other analyses. With the exception of total organic carbon, all analyses were conducted aboard the research vessel shortly after each sample had been collected.

The data collected from the first two monitoring trips are summarized in Tables 2 and 3. During these trips water samples were collected at various distances behind the barge and from several depths at each distance. Although water samples were drawn from a 200-foot depth, the TDC instument was limited by its cable length to 80 feet.

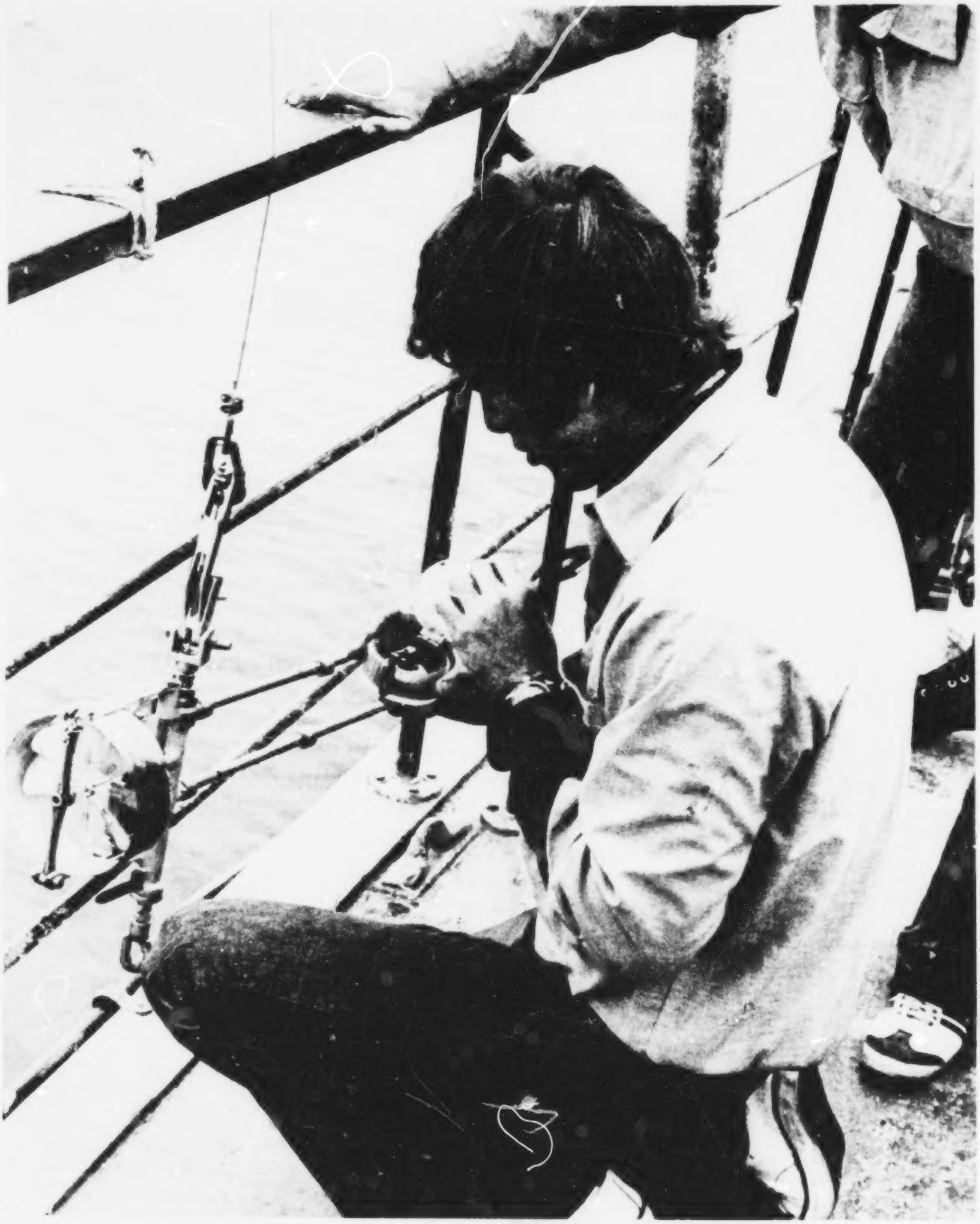

Figure 8. Reading of Current Meter

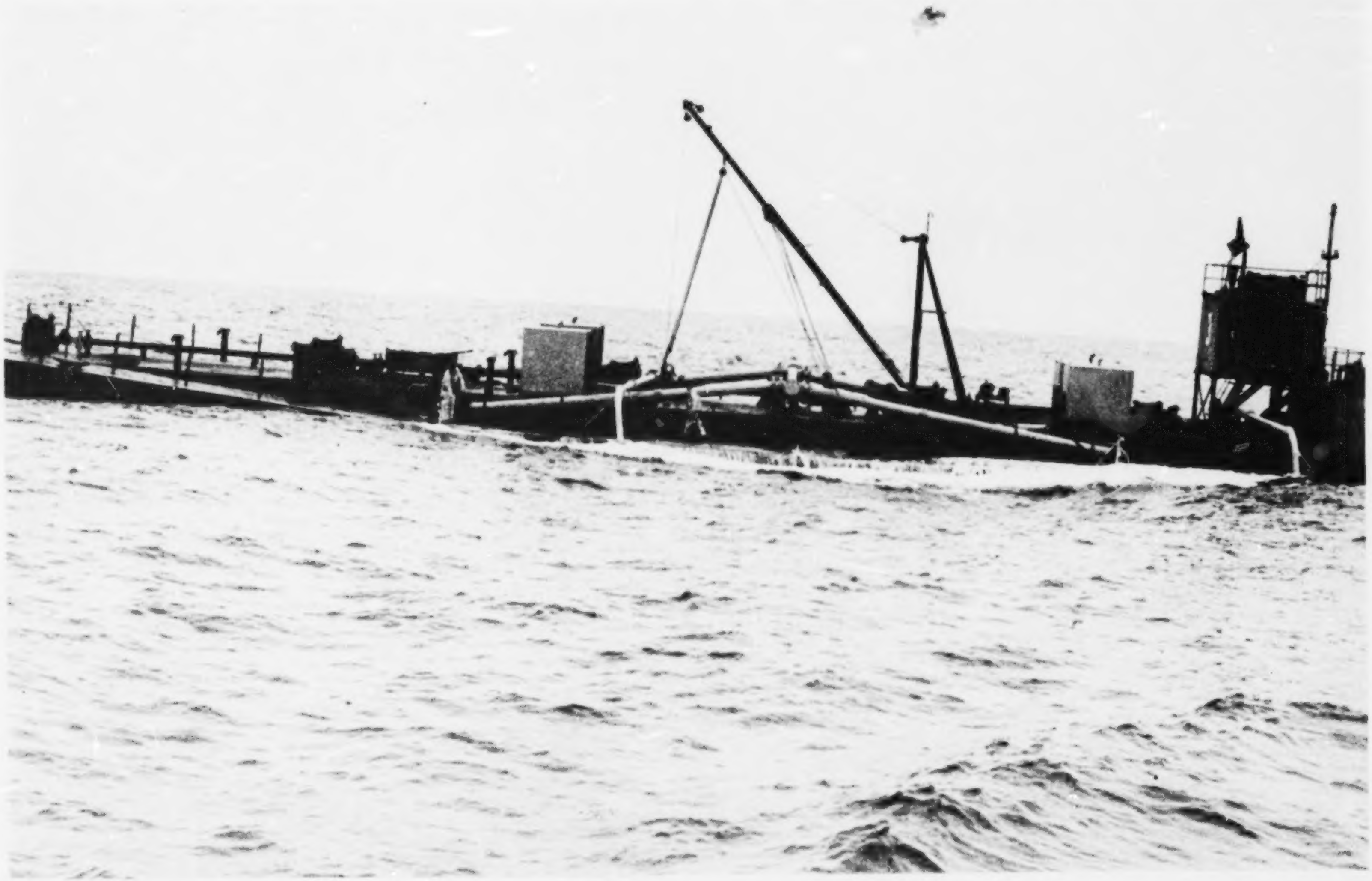

Figure 9. Barge on Location in Discharge Area

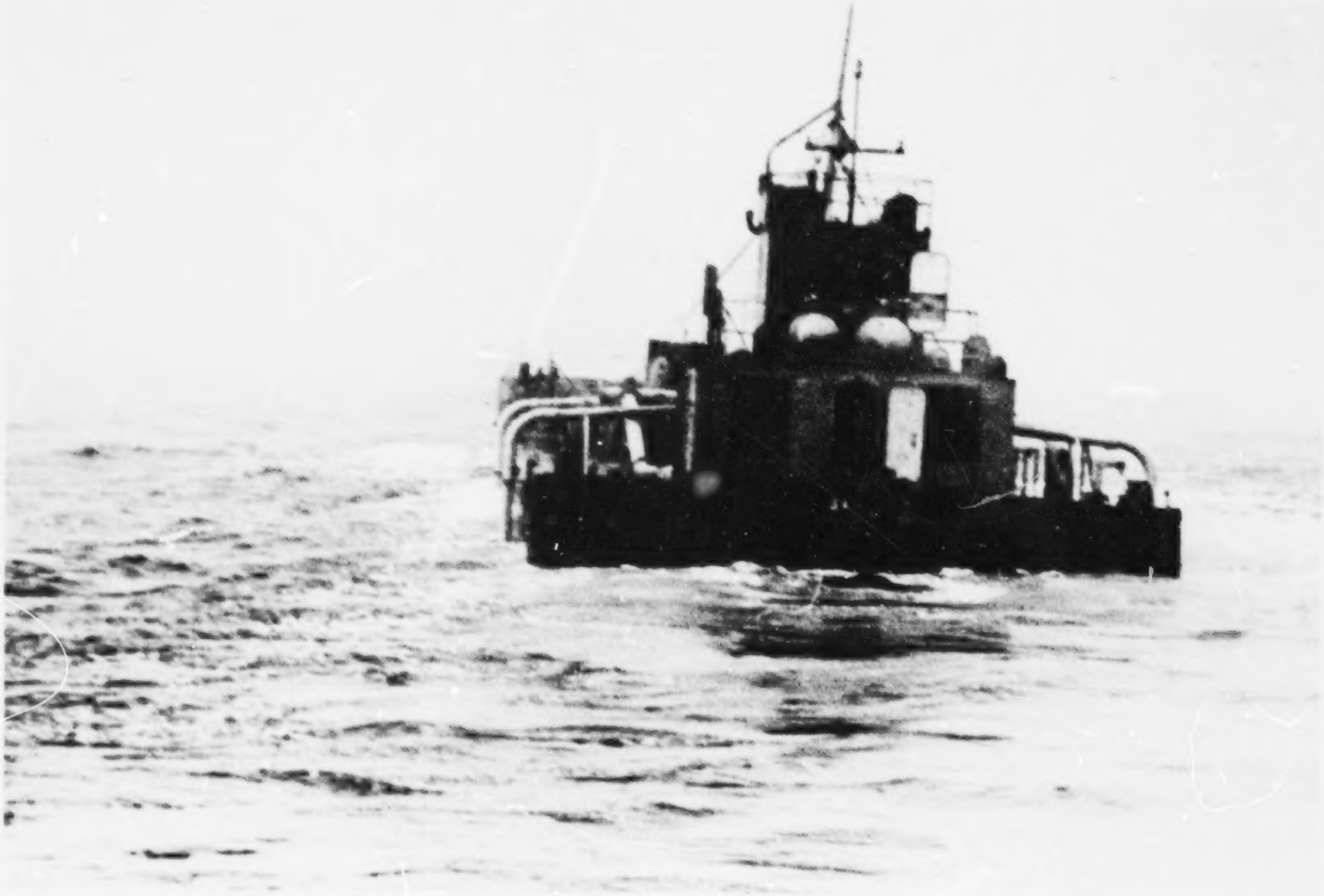

Figure 10. Aft View of Barge

Figure 11. Taking TDC Reading

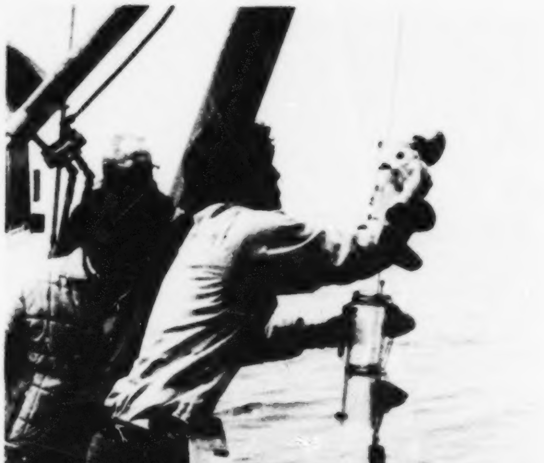

Figure 12. Attaching Samples to Cable

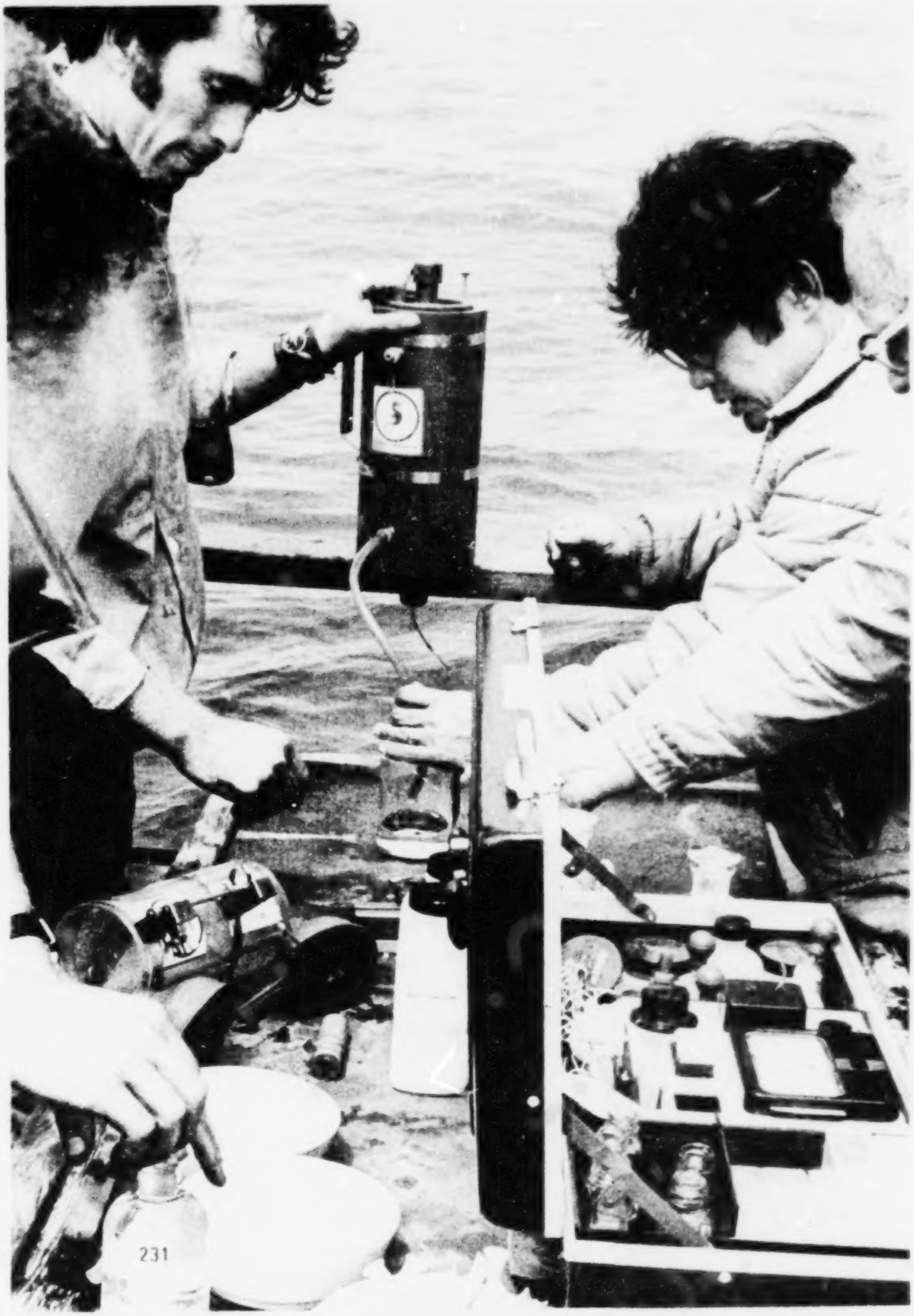

Figure 13. Filling of BOD Bottle After Sample Collection

Figure 14. pH Determination On-Board Monitoring Vessel

Table 2. Ocean Monitoring Data: August 6, 1971

Distance ft	Depth -- inside field						Depth -- outside field					
	1'	10'	20'	40'	80'	200'	1'	10'	20'	40'	80'	200'
	Temperature, °C											
100	13.2	12.3	10.8	----	----	----	----	----	----	----	----	----
500	13.5	12.8	12.0	11.9	9.8	----	13.2	12.8	12.4	11.9	----	----
1000	13.1	12.3	11.0	10.9	10.8	----	13.0	12.8	12.5	11.8	----	----
2000	13.4	13.0	12.8	11.0	10.0	----	13.3	12.5	12.0	10.4	10.8	----
	Conductivity, mmhos/cm											
100	22.8	25.0	25.9	----	----	----	----	----	----	----	----	----
500	25.0	30.3	27.9	23.1	29.1	----	30.0	31.6	30.9	30.9	----	----
1000	33.2	30.9	31.2	26.1	26.4	----	31.6	31.6	31.6	30.0	----	----
2000	28.5	25.0	21.8	28.5	29.1	----	32.3	30.9	30.3	29.1	28.8	----
	Salinity, ppt											
100	18.4	21.0	21.4	----	----	----	----	----	----	----	----	----
500	20.1	25.3	23.6	18.4	26.2	----	24.9	26.0	26.0	26.4	----	----
1000	27.8	26.1	27.4	22.5	22.8	----	26.2	26.2	26.5	25.8	----	----
2000	23.4	20.5	17.6	24.8	26.0	----	26.7	26.0	26.0	25.7	25.1	----
	pH Units											
100	7.95	----	----	----	----	----	----	----	----	7.9	----	7.8
500	7.6	7.9	8.1	----	----	----	8.0	8.1	8.0	----	----	----
1000	----	7.7	7.9	7.8	7.9	7.6	----	----	----	----	----	----
2000	7.8	8.0	8.0	8.0	7.9	7.8	8.1	8.1	8.1	----	----	----
	Dissolved Oxygen, ppm (Winkler)											
100	9.3	----	----	----	----	----	----	----	----	9.1	----	6.1
500	9.0	10.3	9.7	----	----	----	9.6	9.6	9.5	----	----	----
1000	----	----	----	9.0	8.4	4.3	----	----	----	----	----	----
2000	9.1	9.0	9.3	9.6	7.1	5.0	9.1	9.6	9.6	----	----	----

Table 2. (cont'd) Ocean Monitoring Data: August 6, 1971

	Turbidity, % Transmission											
	Depth -- inside field						Depth -- outside field					
Distance ft*	1'	10'	20'	40'	80'	200'	1'	10'	20'	40'	80'	200'
100	98	----	----	----	----	----	----	----	----	98	----	99
500	93	97	97	----	----	----	99	98	98	----	----	----
1000	----	95	97	95	97	98	----	----	----	----	----	----
2000	98	97	98	98	98	100	98	99	99	----	----	----

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*Refers to distance between barge and monitoring vessel at time of data collection

Table 3. Ocean Monitoring Data: August 12, 1971

Distance ft*	Depth -- inside field 1'	10'	20'	40'	80'	200'	Depth -- outside field 1'	10'	20'	40'	80'	200'
	Temperature, °C											
100	10.7	11.7	11.6	11.2	11.2	----	11.7	11.6	11.5	11.2	10.5	----
500	11.5	11.5	11.3	11.0	10.3	----	11.4	11.4	11.3	11.0	10.5	----
1000	11.5	11.5	11.5	11.2	10.4	----	11.5	11.5	11.3	11.4	11.3	----
2000	11.8	11.5	11.4	11.0	10.3	----	11.8	11.8	11.8	11.3	11.0	----
	Conductivity, mmhos/cm											
100	28.5	28.2	28.2	30.9	29.7	----	33.6	33.6	34.4	29.1	31.2	----
500	31.6	30.9	32.3	30.9	30.0	----	33.6	34.4	34.4	31.6	31.6	----
1000	29.1	28.2	27.9	30.9	30.3	----	29.7	28.5	29.7	33.4	33.6	----
2000	29.4	30.0	30.9	30.9	30.3	----	32.8	34.4	33.6	32.8	33.2	----
	Salinity, ppt											
100	25.0	24.0	24.0	26.9	26.4	----	29.2	29.2	30.2	25.4	27.8	----
500	27.3	27.0	28.3	27.2	26.9	----	29.5	30.0	30.0	27.8	28.2	----
1000	25.2	24.2	24.2	27.2	26.9	----	25.7	24.6	25.8	29.2	29.3	----
2000	25.0	26.0	26.0	27.1	27.0	----	28.5	29.7	29.0	29.0	29.4	----
	pH Units											
100	7.50	7.80	7.95	7.50	7.50	----	7.50	7.70	7.65	7.75	7.90	----
500	7.75	7.90	7.90	7.60	7.80	----	7.55	7.85	8.05	7.90	7.50	7.40
1000	7.50	7.60	7.80	7.85	8.00	7.65	7.60	7.80	7.80	7.65	7.85	7.55
2000	7.85	7.85	7.90	7.50	7.40	7.50	7.40	7.65	7.65	8.00	8.05	7.80
	Dissolved Oxygen, ppm (Winkler)											
100	9.2	9.0	9.1	8.8	8.0	----	9.1	9.0	9.0	8.8	8.7	----
500	9.1	8.6	8.6	9.7	8.0	----	9.3	9.3	9.7	9.1	8.5	3.7
1000	8.9	8.8	8.8	8.7	8.7	2.1	8.9	8.9	8.8	9.4	9.3	4.0
2000	8.8	9.0	9.0	9.0	9.7	8.4	8.8	8.8	8.7	9.4	9.6	4.9

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* Refers to distance between barge and monitoring vessel at time of data collection

The parameters listed in Tables 2 and 3 are all interrelated and, as such, should reveal differences between samples collected inside and outside the waste field whenever the discharge of food processing residuals significantly affected the receiving water. Of these parameters, temperature would expectedly be the least indicative since the differential between the ocean waters and the food residuals would be small. Turbidity would probably be the next least likely indicator since the method lacks sufficient sensitivity. However, changes in conductivity or salinity, pH and dissolved oxygen would most readily be observed if there is an effect of the discharge on the receiving water.

The data for the two monitoring trips of August 6 and 12, 1971, did not show a consistent pattern for changes of conductivity or salinity, pH, and dissolved oxygen. When differences between samples collected inside and outside the field were noted, these differences were small. Also, when these differences were noted, the persistence was of a short duration.

On the first monitoring trip, several samples from different distances and depths were not collected. The failure to collect a higher percentage of samples can be attributed to lack of experience and occasional failure of the water sample collection system. On the second trip, very few of the designated samples were omitted, primarily as a result of experience gained from the first trip.

The advisory committee reviewed the data collected from the first two monitoring trips. After a thorough discussion, it was concluded that a third trip would be necessary and that the approach in evaluating the discharge of food processing residuals should be modified.

The primary objective of the third trip was to evaluate the temporal changes in the quality of the receiving waters at a prescribed stationary location. The first two trips were designed to ascertain the degree of any immediate effects on the receiving waters, whereas the third trip was made to determine whether any prolonged changes were created as a result of the discharge. The purpose and procedure of the third monitoring trip are described below.

Third Ocean Monitoring Trip, August 27, 1971

Purpose:

1. Determine the quality of sea water prior to the discharge of food processing solid residuals.

2. During the discharge of food processing solid residuals, determine the immediate effects of the discharge on the quality of ocean water while sampling

at a stationary site with respect to the discharge.

3. Determine the concentration of floating food processing solid residuals with respect to time from a stationary location.

Procedure: I. Before Discharge

- A. Make four water column profiles at 10 foot increments to a depth of 90 feet and determine temperature, salinity and conductivity.
- B. Make two water column profiles at 1, 10, 20, 40, 80 and 200 foot depths and one profile at 10 foot increments to a depth of 200 feet and determine pH, dissolved oxygen and total organic carbon.

II. During Discharge

- A. Mark the waste field by discharging a concentrated solution of dye (Rhodamine B) while the barge is discharging solid waste residuals.
- B. Move monitoring vessel into the waste field and at a distance approximately 500 feet behind the barge. Stop engines and begin sampling program. Manuever vessel as required to remain within wastefield.
- C. At 12 minute intervals and for a period of one hour, collect samples and data at 1, 10, 20, 40 and 80 foot depths. Determine temperature, salinity, conductivity, pH, dissolved oxygen, Rhodamine dye, and total organic carbon. At the end of one hour make a water column profile study at 10 foot increments to a depth of 200 feet and determine pH, dissolved oxygen, Rhodamine dye and total organic carbon.

III. Surface Grab Samples

- A. At time intervals of 1.5, 3, 5, 10, 15, 45 and 60 minutes collect four one gallon grab samples from the water surface. Composite the grab samples and remove a one liter sample for analysis. Blend the one liter sample and analyze for total organic carbon and Rhodamine dye.

Tables 4 through 10 represent data collected from the third monitoring trip. Following the tables, two graphs illustrate some of the more pertinent data collected from the monitoring trip.

Tables 4, 5, and 6 represent data collected at the disposal area prior to discharge. Tables 7, 8, and 9 are data collected after discharge. Table 10 is data for the surface skimmings and indicates the quantity of floatables present at the stationary location.

Table 4. Summary - - Ocean Monitoring Trip August 27, 1971--Before Discharge

Parameter	Series	Depth of Sample in Feet									
		1	10	20	30	40	50	60	70	80	90
Temp °C	1	16.3	16.3	16.0	15.2	13.8	13.0	12.3	11.5	11.2	11.2
	2	16.3	16.3	16.0	15.5	14.3	13.5	13.0	12.3	11.4	11.2
	3	16.5	16.5	16.2	15.3	14.0	13.2	13.0	12.0	11.2	11.2
	4	16.5	16.5	16.2	15.1	13.9	13.5	13.0	12.1	11.3	11.2
Salinity Percent	1	3.10	3.10	3.12	3.08	3.10	2.98	2.98	2.96	2.89	2.84
	2	3.06	3.06	3.00	2.98	2.97	3.04	3.00	2.96	2.88	2.86
	3	2.90	2.90	2.90	2.94	3.01	2.96	2.94	2.94	2.96	2.96
	4	2.92	2.92	2.94	2.95	2.95	2.92	2.94	2.88	2.84	2.86
Conductivity mmho/cm	1	39.8	39.8	39.8	38.2	36.6	35.8	35.0	33.6	32.8	32.3
	2	39.8	39.8	38.2	37.3	36.6	35.8	35.0	34.4	32.8	32.3
	3	38.9	38.9	38.9	37.3	36.6	35.0	35.0	34.4	33.6	33.6
	4	38.2	38.2	38.2	37.3	35.9	34.4	34.4	33.6	32.8	32.3

Table 5. Summary -- Ocean Monntoring Trip August 27, 1971 -- Before Discharge

Parameter	Series	Depth of Sample in Feet					
		1	10	20	40	80	200
pH	1	7.7	7.8	7.9	7.9	8.0	8.0
	2	8.0	8.0	8.1	8.0	8.0	8.0
	3	8.0	8.1	8.1	7.9	7.9	7.9
D.O. ppm	1	8.10	7.95	7.60	8.40	8.60	7.80
	2	8.10	7.50	7.30	8.25	8.50	7.45
	3	7.80	8.20	8.21	8.30	8.55	7.20
Total Organic Carbon ppm	1	27	25	24	26	27	25
	2	22	28	28	24	26	24
	3	22	26	25	31	27	26

Table 6. Summary -- Ocean Monitoring Trip August 27, 1971 -- Before Discharge

Parameter	Water Column Profile Study -- Depth in Feet									
		10*	20	30	40	50	60	70	80	90	100
	1	110	120	130	140	150	160	170	180	190	200
pH	7.7	7.8	7.9	8.0	7.9	8.0	8.0	7.9	8.0	8.0	8.0
		8.0	8.0	7.9	7.9	7.9	8.0	7.9	8.0	7.9	8.0
D. O. ppm	8.10	7.95	7.60	7.65	8.40	8.30	8.50	8.60	8.60	8.10	8.00
		7.50	7.75	8.40	8.00	8.40	7.60	7.75	7.10	7.40	7.80
Total Organic Carbon ppm	27	25	24	25	26	25	26	28	27	27	33
		35	27	31	26	40	27	28	25	24	25

---

* The top value for each parameter refers to depth as indicated on the first horizontal line. The second value refers to depth as indicated by the second horizontal line.

Table 7. Summary -- Ocean Monitoring Trip August 27, 1971 During Discharge

Parameter	Mins.	Depth in Feet				
		1	10	20	40	80
Temp. °C	0	17.0	17.0	16.7	15.1	12.5
	12	16.5	16.5	16.5	15.0	12.3
	24	16.5	16.5	16.5	14.5	12.5
	36	16.7	16.7	16.3	14.5	12.0
	48	16.8	16.6	16.6	14.9	12.3
	60	16.9	16.8	16.5	14.9	12.9
Salinity Percent	0	2.74	2.76	2.86	2.94	2.92
	12	3.02	3.02	3.02	2.96	2.86
	24	2.96	2.96	2.96	2.92	2.94
	36	3.02	3.00	2.90	2.94	2.98
	48	3.00	3.01	2.96	2.95	2.84
	60	3.02	3.02	3.00	2.95	2.92
Conductivity mmho/cm	0	38.2	38.9	38.9	37.3	34.4
	12	38.2	38.2	38.2	36.6	33.6
	24	38.2	38.2	38.2	35.8	34.4
	36	38.9	38.2	37.3	36.2	34.4
	48	38.9	38.9	38.2	36.6	33.6
	60	39.4	39.4	38.9	36.6	33.6

The barge was towed at a speed of three knots, which is equivalent to 5,456 meters per hour, or 91 meters per minute, or 300 feet per minute. The first samples were collected approximately 1.5 minutes after discharge began, which represents a distance of 450 feet behind the barge. Therefore, the stationary sampling location in relation to the moving barge for the different time intervals is as follows:

0 mins = 450 feet
12 mins = 3,600 feet
24 mins = 7,200 feet
36 mins = 10,800 feet
48 mins = 14,400 feet;
60 mins = 18,000 feet

Table 8. Summary -- Ocean Monitoring Trip August 27, 1971 During Discharge

Parameter	Mins.	Depth in Feet					
		1	10	20	40	80	200
pH	0	7.4	7.7	7.8	8.0	7.9	8.0
	12	7.7	7.9	8.0	8.1	8.1	8.0
	24	7.6	7.9	8.0	8.0	8.1	8.0
	36	7.9	7.9	8.1	8.1	8.1	8.1
	48	7.9	8.0	8.1	8.1	8.1	8.0
	60	8.1	8.1	8.1	8.1	8.1	8.1
D.O. ppm	0	7.55	7.60	8.10	7.80	8.40	8.10
	12	7.73	7.90	8.00	9.20	8.90	8.90
	24	6.60	7.05	8.10	8.00	8.50	8.25
	36	7.70	8.00	8.30	8.20	----	8.75
	48	8.00	8.35	8.00	7.60	8.40	8.50
	60	8.00	7.95	8.00	8.30	8.80	8.20
Rhodamine ppb	0	3.3	3.3	1	1	0	0
	12	2.0	1.0	0	0	0	0
	24	12.3	1.0	1	1	0	0
	36	2.0	0	0	0	0	0
	48	0	0	0	0	0	0
	60	0	0	0	0	0	0
Total Organic Carbon ppm	0	60	66	29	26	27	26
	12	45	27	27	26	27	25
	24	37	26	28	27	33	25
	36	29	25	25	20	26	26
	48	33	20	25	25	25	24
	60	32	27	24	25	29	27

Table 9. Summary -- Ocean Monitoring Trip -- August 27, 1971
Water Column Profile 60 Minutes After Discharge

	Depth in Feet										
		10*	20	30	40	50	60	70	80	90	100
Parameter	1	110	120	130	140	150	160	170	180	190	200
pH	8.0	8.0	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
		8.1	7.9	7.9	7.9	8.0	8.0	8.0	8.0	8.0	8.0
D.O. ppm	8.4	8.9	9.0	---	8.5	8.1	8.6	8.0	8.6	8.4	9.0
		8.6	8.5	8.6	8.6	8.5	8.8	8.5	8.7	8.8	8.3
Rhodamine ppb	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0
Total Organic Carbon ppm	24	26	26	25	30	25	27	24	25	28	24
		28	29	28	27	29	26	26	28	22	27

---

* The top value for each parameter refers to depth as indicated on the first horizontal line. The second value refers to depth as indicated by the second horizontal line.

Table 10. Summary -- Ocean Monitoring Trip -- August 27, 1971
Surface Grab Samples

	Time in Minutes							
Parameter	1.5	3.0	5.0	10.0	15.0	30.0	45.0	60.0
Total Organic Carbon ppm	56	58	144	42	37	70	45	37
Rhodamine ppb	5	7	8	2	2	1	0	0

Figures 15 and 16 graphically illustrate some of the data collected from the third monitoring trip. The data for pH and total organic carbon are very similar in illustrating the momentary change as a result of the discharge and the rapid recovery in the quality of the receiving water.

The most noticable pH effect was observed in the initial samples. However, between 20 and 40 feet and greater depths, there was no detectable effect. After 24 minutes the pH change relative to the natural pH was limited to only a depth of less than 10 feet. Beginning with the 36 minute sample, there were no further detectable pH differences between the water before and after discharge.

Regarding total oxygen demand, the same comments as those noted for pH apply. The data collected from the third trip give every indication that the discharge of food processing residuals will change certain water quality characteristics a slight degree, but that there is a rapid return to the natural characteristics and that there are no prolonged effects.

Two arrangements were made to have aerial photographs taken as the barge was discharging. On both occasions overcast weather prevented the photographing of the operation. The primary objective of the photographic mission was to provide an indication of the extent of the surface waste field. We believe the data collected from the three monitoring trips can be used in determining the extent of the waste field.

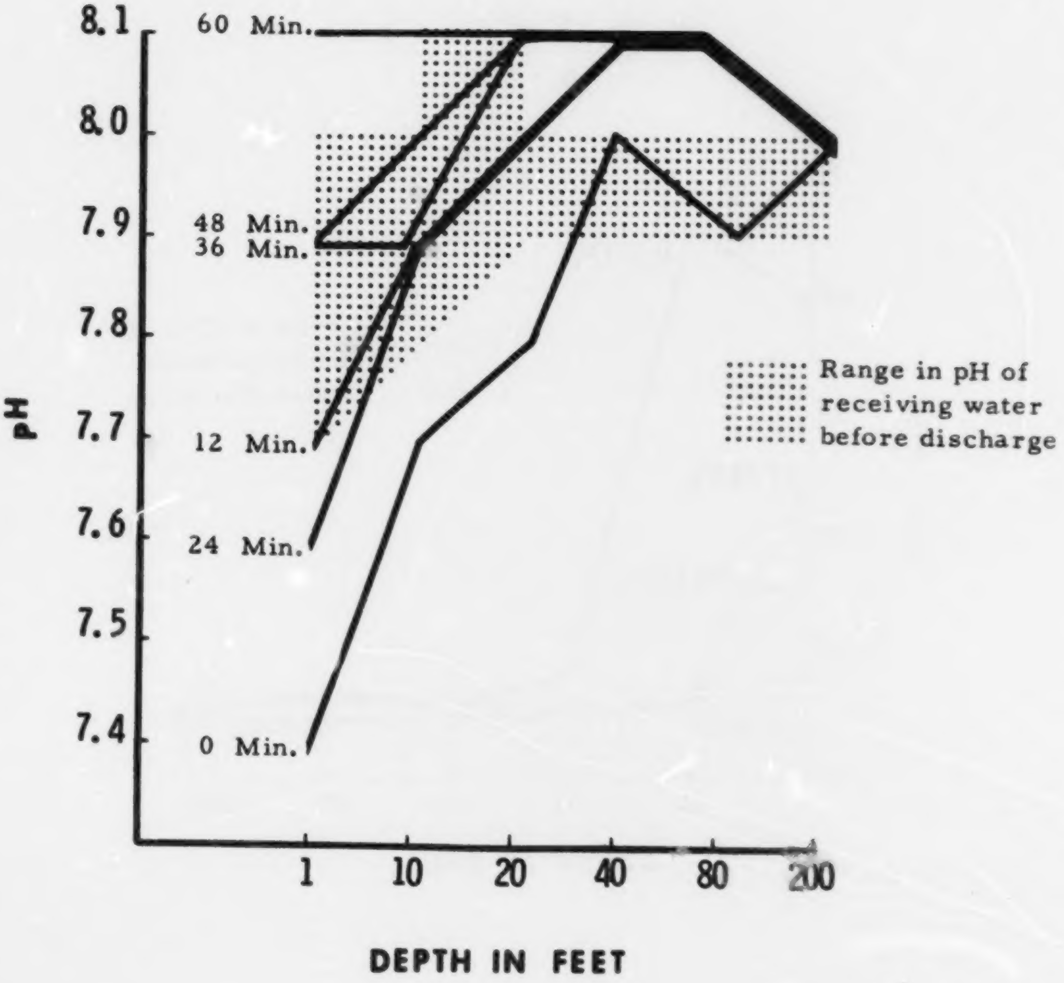

Figure 15 Correlation of Depth and Time with pH

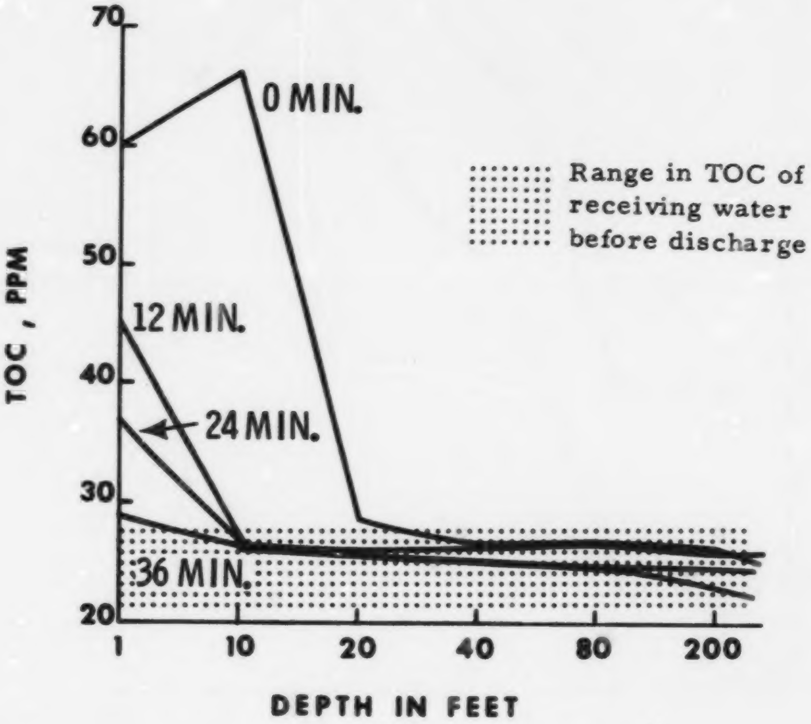

Figure 16 Correlation of Depth and Time with Total Organic Carbon

FISH BIOASSAY

A memorandum from the State Department of Fish and Game to the Regional Water Quality Control Board, San Francisco Bay Region, dated April 26, 1971, outlined the bioassay procedure and the method to be used in establishing the ratio of solids to water.

The advisory committee was again called upon to work out the details of the test procedure which is presented below.

Materials and Supplies

1. Test aquaria - 55 gallon steel drums with polyethelyne liners and PVC piping.
2. Test species - shiner perch.
3. Sea water from Steinhart aquarium

Test Conditions

1. Salinity - approximately that of the receiving water.
2. Temperature - a constant 15°C.
3. Aeration - none except that caused by turbulence in the test tank.
4. Concentration of the sediment - for amount of sediment used, drained but not saturated wet volume.
5. Test concentrations - control plus volume ratios of solids at 1, 3, and 10 times those ratios predicted in the disposal area according to the following rationale:
    a. Calculate the cubic meters of solids to be released into the disposal area during a single disposal operation.

    b. Calculate the surface area in square meters to receive solids during a single operation and multiply this value by the depth of the area in meters or by 3, whichever value is less.

c. The ratio of No. 1 to No. 2 (volume of solids to volume of area receiving solids) may represent the basic test concentration for bioassay. For other concentrations multiply the volume of solids by 3 and 10.

Bioassay Procedure

1. Calculate volumes of water and solids to give desired test concentrations at a total volume of 150 liters.

2. Mix solids and water in test container to 150 liters.

3. Turn on recirculation pump.

4. Introduce a minimum of 10 test fish to each test container. Only one species may be used for a series of bioassays. Test specimens should be of equal size and should not exceed a total weight of 150 grams.

5. After one hour of operation withdraw water sample for determination of:

   a. Dissolved oxygen
   b. pH
   c. Turbidity
   d. Temperature
   e. Suspended solids

6. Repeat of No. 5 each 12 hours.

7. Record number of deaths at 12-hour or less intervals.

8. Bioassay shall run for a minimum of 48 hours.

9. Report number of deaths and results of chemical analyses for 12-hour intervals.

10. Make a tabular comparison of results for control and three concentrations of sediment.

The data used in calculating the basic concentration or ratio of residual to water are as follows:

1. **Barge Dimensions**

a. Length = 165' (50.3 m)
b. Width = 40' (12.2 m)
c. Draft = 9' (2.7 m)
d. Load (Net) = 1040 tons
e. Volume of waste = $\underline{\underline{1658\,\text{m}^3}}$

2. **Receiving Water Volume**

a. Width = 60' (18.3 m)
b. Depth = 10' (3.1 m)
c. Length =
Barge speed = 3 knots
Discharge duration = 3 hrs
3 knots x 1852 m/hr x 3 hrs = $\underline{\underline{16,700\text{ m}}}$

d. Volume:

$$18\text{ m} \times 3\text{ m} \times 16,700\text{ m} = \underline{\underline{9.02 \times 10^5\text{ m}^3}}$$

3. **Basic Test Concentrations**

a. Volume ratio:

$$\frac{1.66 \times 10^3}{9.02 \times 10^5} = 1.84 \times 10^{-3} \text{ or } \frac{1}{542}$$

b. Weight to volume ratio:

$$\frac{2,080,000\text{ lbs}}{902,000\text{ m}^3} = \frac{2.3\text{ lbs}}{\text{m}^3}$$

4. **Test Concentration** (basic)

a. By volume: @ 40 gallons sea water

$$\text{waste volume} = \frac{40}{542}$$
$$= .074\text{ gallon}$$
$$= 280\text{ ml}$$

b. By weight to volume:
40 gallons = .152 m^3 (.00379 m^3/gal)
weight of water = 2.3 lbs/m^3 x .152 m^3
= 0.35 lbs/40 gallons

5. Specified Test Conditions

a. Basic concentration (1x) = 0.35 lbs/40 gallons
b. Three times basic (3x) = 1.05 lbs/40 gallons
c. Ten times basic (10x) = 3.50 lbs/40 gallons

Figure 17 is a schematic drawing of the test aquaria. The test tank is a 55 gallon, 18 gauge, steel drum. Four mil polyethylene bags, 38" x 65", were used as liners. Two liners were used in each drum. All the piping, as well as pump parts that come in contact with water, were constructed from polyvinyl chloride (PVC). To protect the pump intake, a fiberglass tray was constructed and placed at the bottom of the drum. Small holes (1/4") were drilled into the tray to allow free passage of water through the pump. For the first bioassay, a plastic scouring pad was placed over the pump intake at the bottom of the barrel. (The plastic tray, described above, was not used in this first experiment.) The purpose of the tray or pad was to prevent the fish from being sucked up into the recirculation system.

The conditions, variables and results of the first bioassay are given in Table 11.

The test run was terminated after 28 hours with all fish in the control surviving and all other fish dead. Two problems in this experiment were encountered. First, the filter or scouring pad over the pump inlet became clogged and reduced the recirculation flow. Second, subsurface discharge did not provide sufficient oxygenation to meet the demand exerted by the solid residuals.

To overcome the problem of clogging of the pump intake, it was necessary to use another method. It was decided for the next bioassay to use the fiberglass tray as previously described. Figure 18 is a photograph looking down into a test tank. The fiberglass tray with perforated holes can be seen at the bottom.

In the second bioassay, efforts were made to satisfy the oxygen demand by having the discharge end of the recirculation system spray the water up into the air and splash along the inside of the barrel. Figure 19 is a photograph showing the recirculation system discharging above surface on the left, and the submerged discharge as used in the first bioassay on the right.

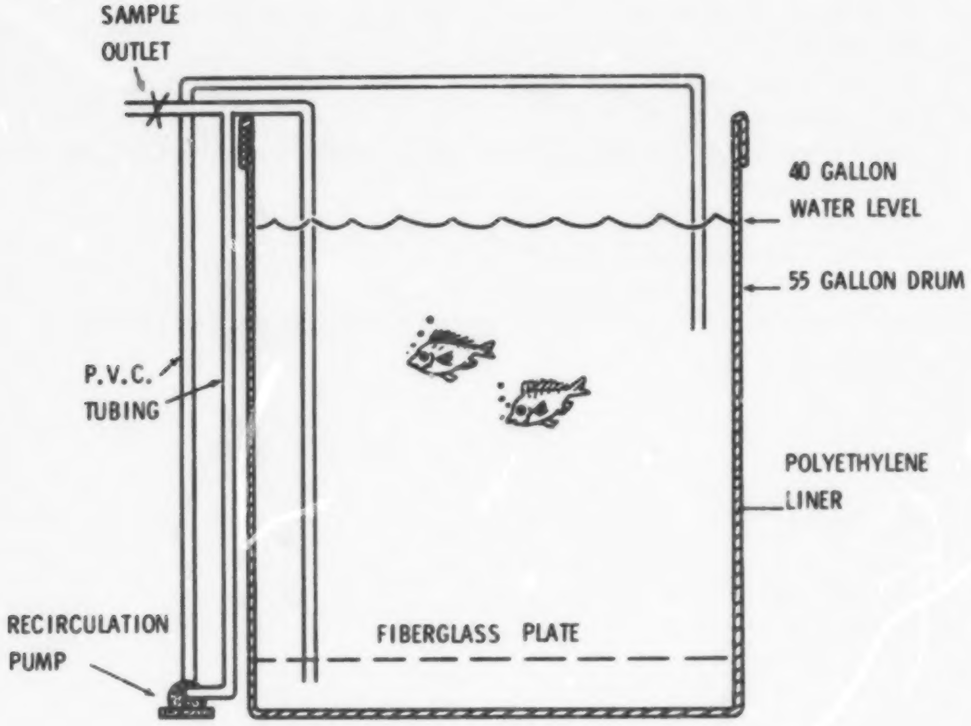
SAMPLE OUTLET
40 GALLON WATER LEVEL
55 GALLON DRUM
P.V.C. TUBING
POLYETHYLENE LINER
RECIRCULATION PUMP
FIBERGLASS PLATE

Figure 17 Schematic of Test Aquaria

Table 11. Fish Bioassay No. 1 July 21-22, 1971

A. Conditions

1. Test fish - shiner perch, 10 per barrel, average weight, 15 grams.
2. Water - sea water from Steinhart Aquarium, 40 gallons each barrel.
3. Test container - 55 gallon steel drum with two polyethylene bag liners.
4. Temperature - 15°C.
5. Waste - ground peach-pear.
6. Plastic scouring pads over pump inlet.
7. All barrels had recirculation pump discharge below surface of water.

B. Variables

1. Barrel No. 1 = control
2. Barrel No. 2 = 0.75 lbs of solids
3. Barrel No. 3 = 2.25 lbs of solids
4. Barrel No. 4 = 2.25 lbs of solids
5. Barrel No. 5 = 5.75 lbs of solids

C. Results

Barrel No.	Hours	Dissolved Oxygen, ppm	Suspended Solids, ppm	pH
1	1	7.0	10	7.5
2	1	6.5	30	7.0
3	1	5.4	149	6.5
4	1	6.1	191	6.6
5	1	3.9	356	6.1
1	6	6.4	---	7.5
2	6	3.9	---	6.9
3	6	4.1	---	6.5
4	6	3.5	---	6.6
5	6	3.1	---	6.1
1	28	7.3	5	7.4
2	28	0.0	23	6.2
3	28	0.0	192	5.6
4	28	0.0	59	5.7
5	28	1.1	53	6.1

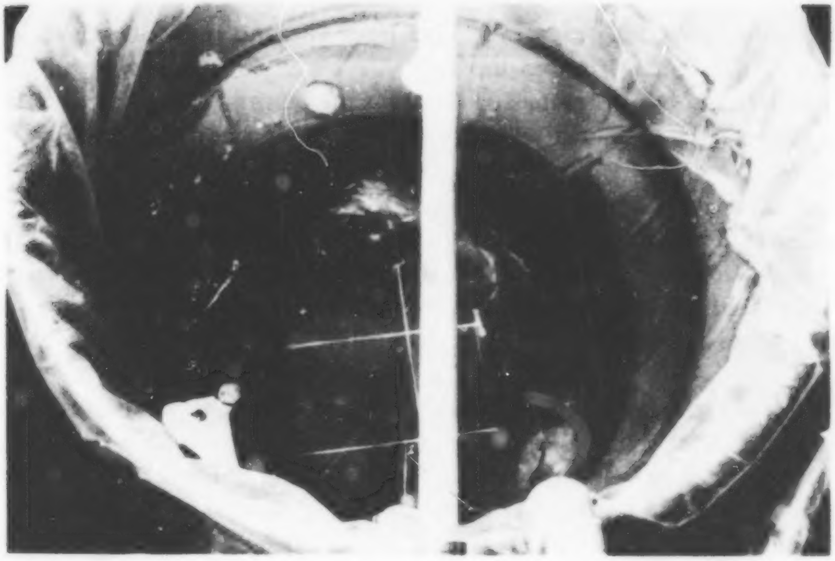

Figure 18. View Looking Down into Test Tank

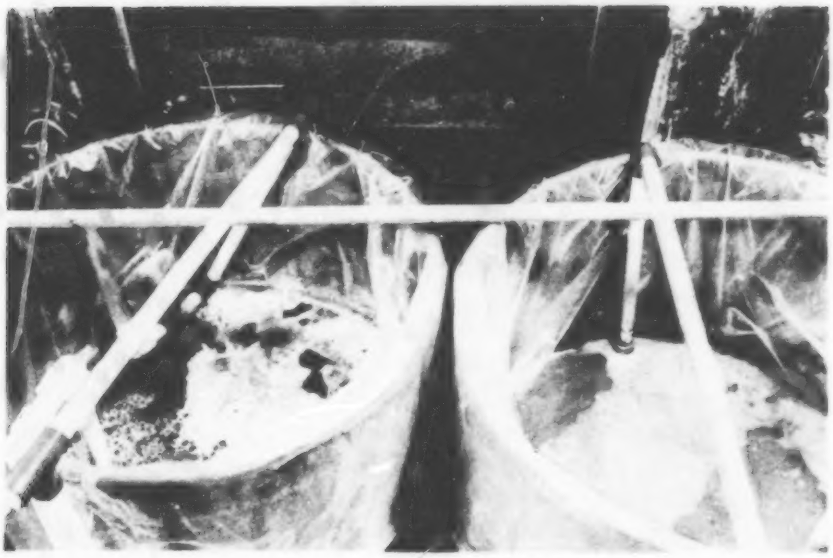

Figure 19. Above and Below Surface Discharge of Recirculation System

The conditions, variables, and results are tabulated in Table 12.

The test ran for the prescribed 48 hours, then was terminated. After 24 hours, all of the fish in barrel No. 1 were dead, and one dead fish in barrel No. 2 was noticed. At the end of the 48 hours, a fish count was again made in barrel No. 2 with all remaining fish alive.

The pH in barrel No. 2 was adjusted after the 30-hour sample had been collected. The pH had dropped to a value of 4.6 and would have continued to drop as the carbohydrates in the solids fermented. To eliminate possible side effects caused by the pH during the test period, sodium hydroxide was added to bring up the pH.

In this experiment, the previous one, and those that followed, it was impossible to see the fish in the tanks after solids had been added. The visibility was limited to only a few inches of depth. Several efforts were made to devise a means for counting the fish during the test period. One method which was partially successful was to use a submersible high-powered flashlight. The final fish count was accomplished at the end of the test period by draining the water from the drums and counting the survivors.

Following the results of the second bioassay in which it was demonstrated that the oxygen demand could be satisfied by using above-surface discharge, a third bioassay was set up using three concentrations or ratios of waste to water, a control, and comparison again between surface, and subsurface discharge of the recirculation system. The conditions, variables, and results are given in Table 13.

The results again confirmed the previous test findings in that the use of a submerged discharge was not adequate to meet the oxygen demand of the system. This deficiency was overcome by discharging above the surface. It was not necessary to neutralize with hydroxide during the test period, although after 48 hours, the pH in barrel No. 5 had dropped to a value of 4.5.

Following these three bioassays, a meeting was held to discuss the findings. Concern was expressed that re-aeration through discharge above the surface would result in the loss of volatile compounds from the test container. Although it was pointed out that food processing residuals contain only a very small percentage of volatile compounds and that none of these were toxic, it was agreeded that a bioassay

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Table 12. Fish Bioassay No. 2 July 26-28, 1971

A. Conditions

1. Test fish - shiner perch, 10 per barrel, average weight, 15 grams.
2. Water - sea water from Steinhart Aquarium, 40 gallons each barrel.
3. Test Container - 55 gallon steel drum with two polyethylene bag liners.
4. Temperature - constant 15°C.
5. Waste - 5.6 pounds of ground peach-pear.
6. Filter - pump inlet enclosed inside plastic tray.

B. Variables

1. Barrel No. 1 - submerged 3 inches below water surface.
2. Barrel No. 2 - discharge above surface.

C. Results

Barrel No.	Hours	Dissolved Oxygen, ppm	pH
1	0	7.8	7.5
2	0	7.8	7.5
1	1	7.2	6.6
2	1	7.4	6.8
1	6	6.4	6.4
2	6	7.1	6.6
1	12	5.0	6.2
2	12	6.0	6.7
1	24	2.4	5.1
2	24	4.6	5.2
1	30	4.0	4.6
2	30	5.7	4.7
1	36	4.9	4.4
2	36	6.2	8.8
1	48	6.5	4.4
2	48	6.5	6.5

Table 13. Fish Bioassay No. 3 September 5-7, 1971

A. Conditions

1. Test fish - shiner perch, 10 per barrel, average weight 15 grams.
2. Water - sea water from Steinhart Aquarium, 40 gallons each barrel.
3. Test container - 55 gallon steel drum with two polyethylene liners.
4. Temperature - constant 15°C.
5. Waste - ground peach-pear solids.
6. Filter - pump inlet enclosed inside plastic tray.

B. Variables

Location of the recirculation pump discharge and amounts of waste in each barrel.

Barrel No.	Lbs of Waste	Pump Discharge Location
1	0.634	Submerged recirculation outlet
2	1.90	"
3	6.34	"
4	6.34	Above surface
5	6.34	"
6	Control	Submerged recirculation outlet
7	1.90	Above surface

C. Results

Barrel No.	Hrs	Oxygen, ppm	pH	Solids, ppm	Turbidity	Remarks
1	0	8.1	---	---	---	---
2	0	8.05	---	---	---	---
3	0	7.9	---	---	---	---
4	0	7.9	---	---	---	---
5	0	8.0	---	---	---	---
6	0	8.3	---	---	---	---
7	0	8.2	---	---	---	---

Table 13. Fish Bioassay No. 3 (continued)

C. Results (continued)

Barrel No.	Hrs	Oxygen, ppm	pH	Solids, ppm	Turbidity	Remarks
1	1	7.9	7.5	88	65	---
2	1	7.1	7.1	136	112	---
3	1	6.35	6.25	310	280	2 fish dead
4	1	6.9	6.9	136	240	---
5	1	7.0	6.8	332	250	---
6	1	7.95	7.75	16	< 25	---
7	1	8.0	7.4	98	90	---
1	14.5	0.5	6.7	64	60	---
2	14.5	0.2	6.5	208	140	---
3	14.5	0.4	6.0	312	310	---
4	14.5	5.3	6.8	260	260	---
5	14.5	5.9	7.0	460	300	---
6	14.5	5.7	7.5	12	< 25	---
7	14.5	7.6	7.4	144	130	---
1	24	0	6.1	44	130	---
2	24	0	4.8	136	180	---
3	24	0	5.0	228	270	---
4	24	2.3	6.4	232	350	---
5	24	2.7	6.4	316	360	---
6	24	4.5	7.3	9	< 25	---
7	24	7.4	6.9	86	120	---
1	48	0.2	6.1	---	57	10 fish dead
2	48	0.3	4.5	---	150	10 fish dead
3	48	0.0	4.3	---	300	10 fish dead
4	48	3.0	6.0	---	350	5 living, 7 dead
5	48	4.6	4.5	---	300	7 living, 3 dead*
6	48	4.0	7.0	---	< 25	11 living
7	48	7.5	7.1	---	90	12 living

---

* One of the 3 counted as dead had died just after the conclusion of the test.

would be run with submerged discharge and some other method of re-aeration.

It was suggested that oxygen be bubbled into the water as a means of satisfying the oxygen demand. Figure 20 is a view of the constant temperature room. To the right is an oxygen cylinder and at the top of the picture is a manifold with tubing leading down to each of the barrels.

A test, using three concentrations of residuals, was again conducted. Oxygen was bubbled into the tanks at a rate prescribed by Standard Methods. This method did not maintain sufficient dissolved oxygen in the water, and the test was terminated after 24 hours.

It was then decided to use fritted glass diffusers to break up the oxygen bubbles into very fine bubbles. By this time, shiner perch were no longer available as the test species. Permission was granted to use stickleback in the bioassay.

Table 14 lists the conditions, variables and results for the bioassay using oxygen and fritted glass diffusers.

After the 60-hour samples had been collected, the water from barrel No. 4 was transferred to another barrel to facilitate a fish count. It was possible to see the surviving fish in the other tanks. At the end of 96 hours, the water was drained from each of the barrels to confirm the number of survivors. All test tanks had 100% survival.

As shown by the results, there was no pH problem nor dissolved oxygen problem. The use of fritted glass diffusers greatly enhanced the dissolution of gaseous oxygen into the water. During most of the test, super saturation values of D.O. were recorded. The oxygen flow to the tanks was periodically adjusted manually by reducing or increasing the gas flow. The control tank did not show high D.O. levels since oxygen was simply bubbled directly into the water rather than being passed through a diffuser.

In the earlier bioassays, more than the actual ratio of solids to water was used. Because of a calculation error, approximately twice the amount of solids was used than the final calculation called for. In other words, some bioassays were performed with ratios 2, 6, and 20, rather than 1, 3, and 10. Even under these more severe conditions, fish survival was possible. Figure 21 photographically illustrates the appearance of the three calculated ratios of waste solids to water.

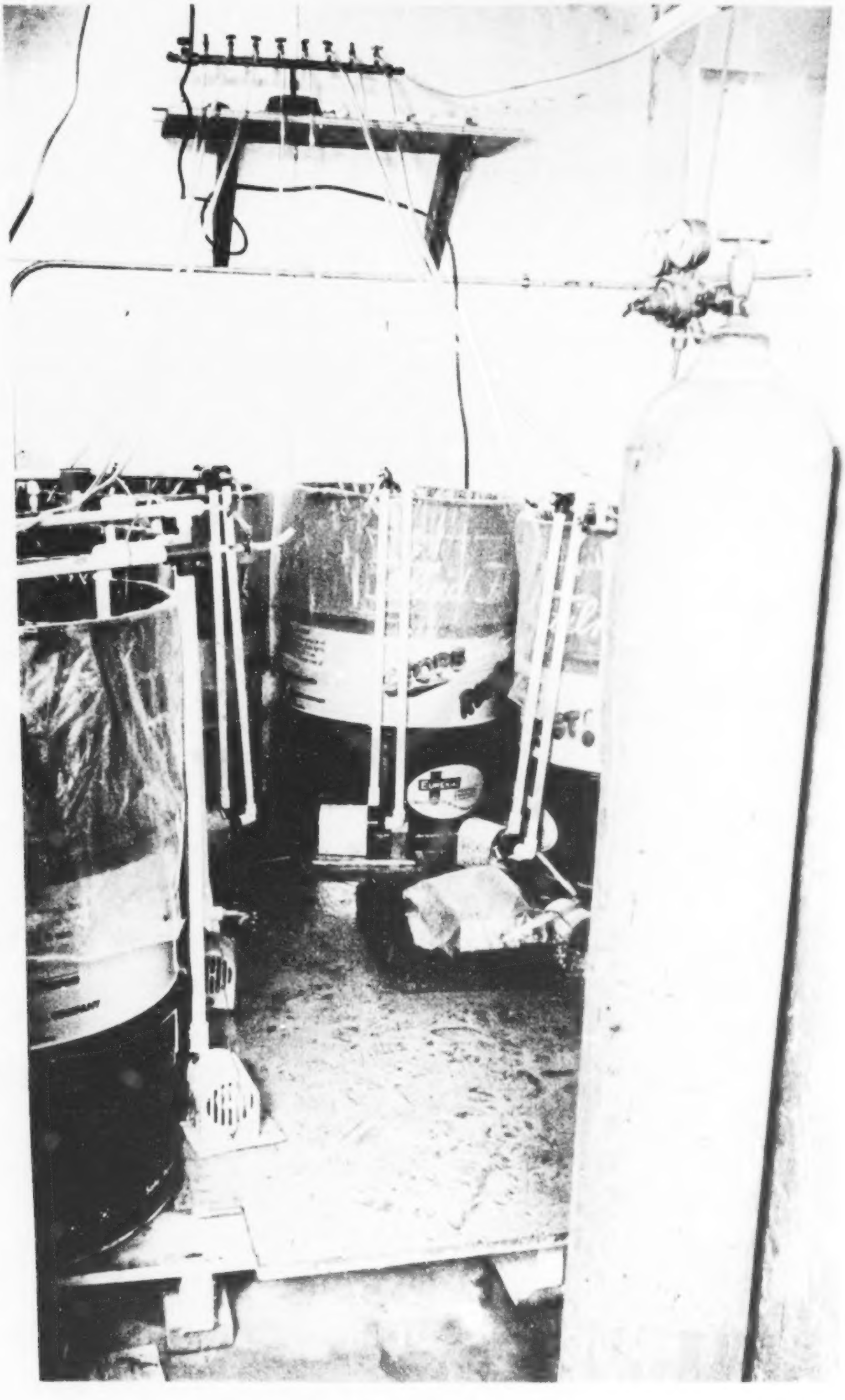

Figure 20. Constant Temperature Bioassay Room

Table 14. Fish Bioassay No. 4 October 11-15, 1971

A. Conditions

1. Test fish - stickleback, 10 per barrel.
2. Water - sea water from Steinhart Aquarium, 40 gallons each barrel.
3. Test container - 55 gallon steel drum with two polyethylene liners.
4. Temperature - constant 15°C.
5. Waste - ground peach-pear solids.
6. Filter - pump inlet enclosed inside plastic tray. Cheesecloth wrapped around outside of plastic tray.

B. Variables

1. Barrel No. 1 = control
2. Barrel No. 2 = 0.35 lbs waste
3. Barrel No. 3 = 1.05 lbs waste
4. Barrel No. 4 = 3.50 lbs waste

C. Results

Period: 0 hrs

Sample	pH	D.O.*
control	7.6	7.7
1x	7.8	7.6
3x	7.8	7.7
10x	7.8	7.5

Period: 12 hrs

Sample	pH	D.O.	S.S.**	Turbidity***
control	7.4	11.1	26	< 25
1x	7.3	34.5	29	< 25
3x	7.0	27.0	35	25
10x	6.9	34.3	65	71

---

* D.O. = Dissolved oxygen, ppm

** S.S. = Suspended solids, ppm

*** Turbidity = JC units

Table 14. Fish Bioassay No. 4 (continued)

C. Results (continued)

Period: 24 hrs

Sample	pH	D.O.	S.S.	Turbidity
control	7.4	9.0	15	< 25
1x	7.2	24.0	24	< 25
3x	6.9	18.8	35	< 25
10x	6.5	28.4	50	59

Period: 36 hrs

Sample	pH	D.O.	S.S.	Turbidity
control	7.4	8.5	12	< 25
1x	7.2	24.7	28	< 25
3x	7.0	20.0	32	< 25
10x	6.4	17.5	54	53

Period: 48 hrs

Sample	pH	D.O.	S.S.	Turbidity
control	7.6	8.6	15	< 25
1x	7.5	27.0	47	< 25
3x	7.5	25.0	31	< 25
10x	6.6	11.0	52	46

Period: 60 hrs

Sample	pH	D.O.	S.S.	Turbidity
control	7.2	11.4	0	< 25
1x	7.2	9.9	30	< 25
3x	7.1	33.5	36	< 25
10x	6.6	32.1	55	40

Table 14. Fish Bioassay No. 4 (continued)

C. Results (continued)

Period: 72 hrs

Sample	pH	D. O.	S. S.	Turbidity
control	7.2	8.0	44	< 25
1x	7.1	27.6	62	< 25
3x	6.9	19.4	55	< 25
10x	6.2	13.8	64	37

Period: 84 hrs

Sample	pH	D. O.	S. S.	Turbidity
control	7.5	11.3	51	< 25
1x	7.4	27.5	40	< 25
3x	7.4	19.9	60	< 25
10x	6.9	21.1	78	< 25

Period: 96 hrs

Sample	pH	D. O.	S. S.	Turbidity
control	7.1	10.1	49	< 25
1x	7.1	23.2	41	< 25
3x	7.1	16.4	60	< 25
10x	6.8	18.2	76	< 25

It is believed that all data in this report, the characterization of the solids, the monitoring trips, and the bioassay provide the necessary information to state that food processing solid residuals are non-toxic and can be discharged into the marine environment without detrimental effects to the quality of the receiving water or the marine life.

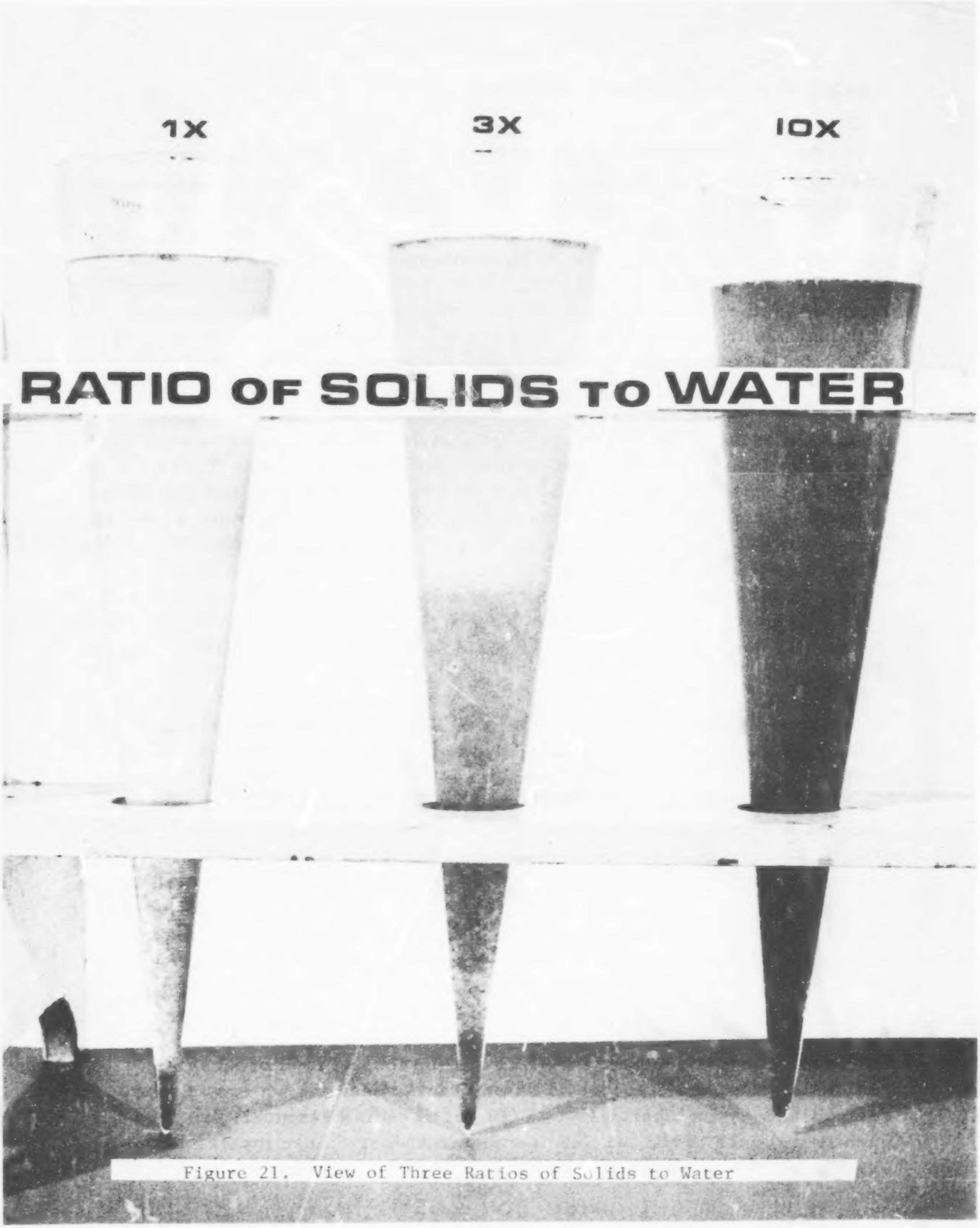
1X
3X
IOX
RATIO OF SOLIDS TO WATER

Figure 21. View of Three Ratios of Solids to Water

ALTERNATE METHODS OF DISPOSAL

According to a recently completed survey (in publication) the food processing industry annually generates over 9 million tons of food residuals during the canning, freezing and dehydrating of fruits, vegetables and seafoods. Of the total quantity of food residuals, approximately 75% is utilized for by-products, primarily as animal feed; about 20% of these materials are disposed of as solid waste; largely through land disposal methods; some 3% is disposed of in a liquid medium, most frequently with processing wastewaters. The method which is utilized for disposal of residuals from any processing plant is dictated by numerous factors, as discussed below.

About 5.6 of the 7.1 million tons of residuals which are used as feed are from only three products: citrus, corn, and white potatoes. These are all large crops, producing large percentages of residuals, and generally processed in regions where there are livestock to consumer the residuals. Citrus and potatoes are processed the year around and corn residuals are converted to ensilage which can be stored; these by-products are, therefore, available as dependable sources of feed materials. Thus, the two limiting factors which determine the practicality of utilizing food residuals for animal feed are proximity to livestock-raising areas and dependability of supply.

Of the approximately 1.7 million tons of residuals which are handled as solid waste, equal quantities are disposed of by landfill and spreading techniques. Minor quantities of dry residuals are incinerated. However, land disposal methods require adequate areas of land which are suitably isolated from residental areas. Fill methods, whether as sanitary landfills or by cut-and-fill techniques, must be employed with careful consideration of potential groundwater, as well as surface water, contamination. In both cases, land used for disposal purposes generally has limited utility for extended periods after cessation of disposal operations. Although spreading, with subsequent discing, of agricultural residues and food processing residuals is a common practice in rural areas, the space requirements for this method of disposal are generally excessive.

By far the largest portion of the 0.3 million tons of food processing residuals which are disposed of directly into receiving waters is from seafood processing operations. Fish and shellfish residuals are frequently returned to the marine environment where these materials reenter the natural food-chain. Additionally, food residual solids are in some inland situations discharged into lagoons, industrial treatment systems, municipal sewage treatment plants and, in minor quantities and very few instances, directly into receiving streams. However, the frequency with which solids are discharged with processing wastewaters is rapidly diminishing, due primarily to the increased difficulty of treating such industrial wastewater to the degrees necessary to comply with increasingly stringent discharge requirements.

To bring this discussion to a regional basis and closer to the case in point, attention can be limited to two major fruit commodities -- peaches and pears. In California a total of 245,000 tons of peach residuals (84% of the national total) are annually generated. Of the combined total, 330,000 tons, about 107,000 tons are disposed of by fill methods, about 77,000 tons by spreading techniques, some 23,000 tons in water -- namely, ocean discharge, and 69,000 tons as animal feed. The remainder is utilized for various by-products, such as charcoal manufacture and alcohol production. However, a recently implemented program of spread and discing will shift a significant quantity from the fill-disposal residual total to the spreading method.

Regarding alternate methods of disposal available to the food processors located in the East Bay, the choices appear all to few. By-product conversion is, of course, the most desirable avenue. However, serious limitations are imposed by current state-of-the-arts and economic factors. Charcoal manufacture is limited to utilization of peach pits; all recoverable pits are now so being utilized. Alcohol production is limited by the seasonality of the fruit operations and the handling capabilities of local wineries. Animal feed is rendered impractical by the seasonality and the distance to livestock-raising areas.

Although sanitary landfill sites are used extensively for the disposal of domestic refuse and most industrial wastes, the number of such sites in the East Bay are limited; many are rapidly being filled to capacity. For the most part, these sites are located directly adjacent to San Francisco Bay and are therefore subject to salt water infiltration and subsequent dangers of water pollution. The high moisture content of fruit residuals enhances the potential occurence of leachate, thereby further limiting the use of available landfill sites.

Spread and discing disposal operations appear to be the most promising alternative method. However, large acreage must be available to properly conduct such oerations in a manner which will prevent or minimize the occurrence of environmental problems. Urban expansion in the East Bay has been proceeding at an accelerated rate during the past several years. This urbanization process has made unavailable the required acreage with sufficient isolation to permit land disposal operations within relatively close proximity to the food processing plant. Therefore, although a spread and discing operation is a feasible alternative, the implementation of such an operation can be realized only through a considerable capital outlay and increased transporation costs due to significantly longer hauling distances. Furthermore, there can be no assurances that urban encroachment will not quickly render such an operation impossible.

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Advisory Committee

Mr. Robert E. Hillman	Hunt-Wesson Foods
Mr. Nick Pateman	Hunt-Wesson Foods
Mr. Herbert E. Stone	Del Monte Corporation
Mr. Jack Liebig	Stokely-Van Camp
Mr. Lou Schmitz	Oakland Scavenger Co.
Mr. Lawrence K. Taber	Canners League of California
Dr. Teng-chung Wu	California Regional Water Quality Control Board - S.F. Bay Region
Mr. Richard Wood	California Regional Water Quality Control Board - S.F. Bay Region
Mr. John Ladd	California Dept. of Fish and Game
Mr. Allen M. Katsuyama	National Canners Association
Mr. Richard W. Sternberg	National Canners Association
Mr. Walter A. Mercer	National Canners Association
Mr. Walter W. Rose	National Canners Association

Listed above are the names and affiliations of committee members and others who provided valuable assistance and guidance throughout this study. Without their help the task of carrying out the program would have been most difficult.

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PROCESS DESIGN FOR TREATMENT OF CORN WET MILLING WASTES

by

H. O. Bensing* and D. R. Brown**

INTRODUCTION

Starch has been manufactured from corn commercially for more than 100 years. In the early days of the industry, only starch was recovered; all the other components of the kernel were discarded.

Toward the end of the 19th century the corn millers began to realize that the non-starch fraction of corn had value as an animal feed.(1) Later, a process for separating germ and recovering the corn oil was developed. Improved methods for steeping the corn permitted evaporation of the steepwater, and recovery of the solubles as part of the animal feed. By the beginning of the 20th century, practically all of the corn kernel was being recovered, including a large fraction of the solubles.

There remained, however, one large source of liquid waste. Water used for washing solubles from the starch was sewered. These solubles, amounting to about 2% of the corn, must be removed to obtain the best quality starch and syrup products.

CLOSING THE LOOP

For many years this wash water stream was considered too dilute to recover. However, a study was started in 1920 at the Argo plant of Corn Products Refining Company (now CPC International, Inc.), in cooperation with the Chicago Sanitary District, which resulted in a process in which the wash waters were used for steeping the corn.(2, 3) The resulting "bottled up" wet milling process (Figure 1) is now standard throughout the industry.

Corn is steeped by soaking in process waters. The resulting water is evaporated to concentrate the solubles, and can be used as an additive to the animal feed products, or sold separately as a liquid cattle feed or a nutrient for antibiotic fermentations.

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*CPC International, Inc., Industrial Division, Pekin, Illinois.
**CPC International, Inc., Industrial Division, Moffett Technical Center, Argo, Illinois

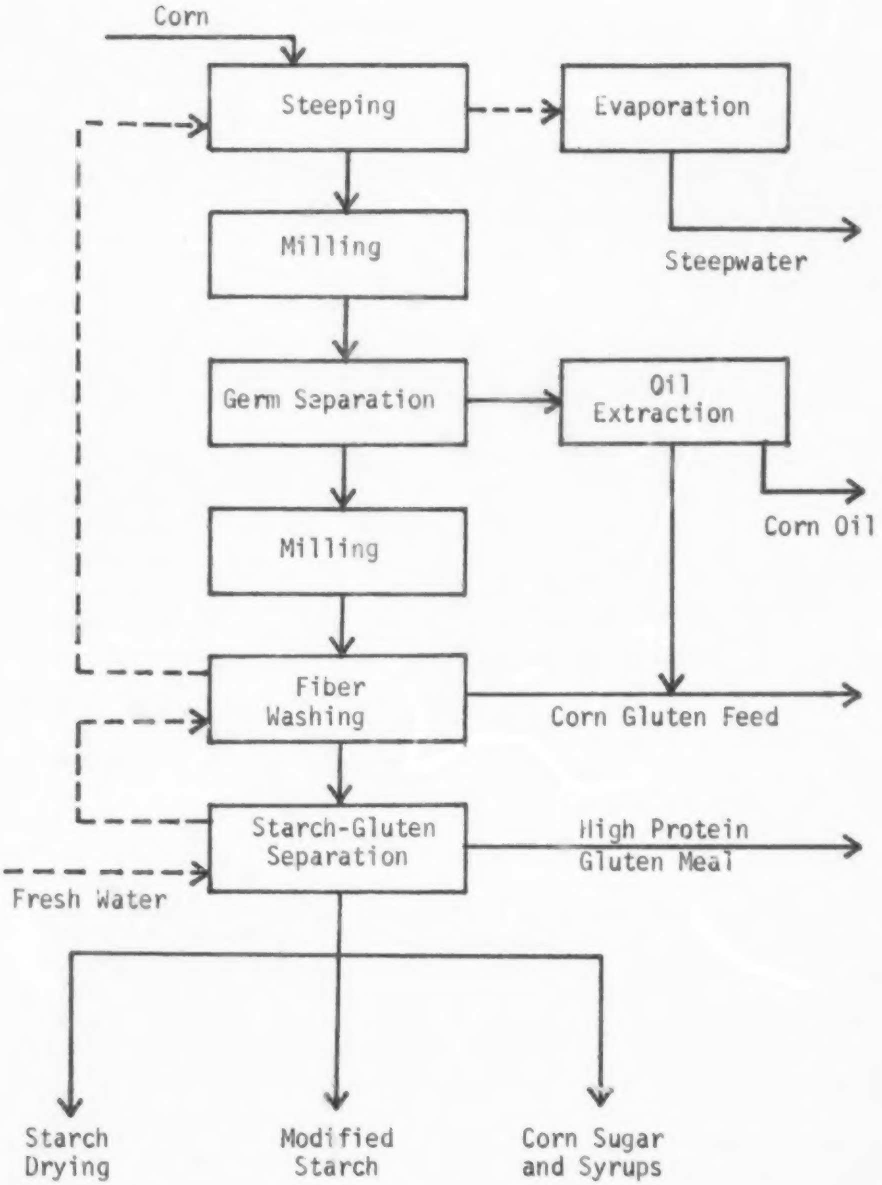
Corn
Steeping
Evaporation
Steepwater
Milling
Germ Separation
Oil Extraction
Corn Oil
Milling
Fiber Washing
Corn Gluten Feed
Starch-Gluten Separation
High Protein Gluten Meal
Fresh Water
Starch Drying
Modified Starch
Corn Sugar and Syrups

Figure 1. Corn Wet Milling Process

After steeping, the corn is mildly milled, to break open the kernel, and release the germ with as little damage as possible. The germ is separated from the other components of the kernel with hydroclones, and then dried and processed to extract the corn oil. The oil free germ is added to the animal feed.

After separating the germ, the remainder of the starch and gluten is released from the hulls. The free starch and gluten are separated from the hulls by countercurrent washing and screening. The hulls are dried, and combined with the concentrated steepwater and the oil free germ from previous steps to make corn gluten feed.

The mixture of starch and protein that were separated from the hulls are processed through centrifuges and a series of small diameter hydroclones. This results in separation of the starch and protein, as well as removal of solubles from the starch.

The protein fraction, referred to as corn gluten, is concentrated, filtered, and dried. The product is principally used as a high protein additive to feeds for broilers.

Fresh water is added to the hydroclone station, at the rate of about 12 to 15 gallons per bushel of corn processed. A significant portion of this water consists of condensates recovered during evaporation of finished products.

The finished starch product, still in slurry form, may be dried directly as an unmodified starch, or treated by various chemicals to make modified starch. Part of the starch stream is hydrolyzed with acid, enzymes, or a combination of acid and enzymes to produce corn syrup or dextrose.

WASTE SOURCES

The process shown in Figure 1 is usually referred to as the wet starch process. The only waterborne waste from the wet starch process is the condensate resulting from the evaporation of steepwater. The condensate contains volatiles which are formed during the steeping process, and are vaporized during evaporation.

The sources of other liquid wastes vary within the wet milling industry, depending on the products made and the processes used. Typically, in addition to the volatiles, the waste stream might contain filtrates from the preparation of modified starches, with dissolved chemicals used for modification, and some soluble carbohydrate formed during the process. Another source of waste is the impurities removed during the refining of corn syrups and dextrose.

These volatiles and carbohydrates exert an oxygen demand when discharged to a stream or to a municipal treatment plant. This has been recognized for many years, and various treatment methods have been developed by members of the wet milling industry.(4, 5, 6)

WASTE CONTROL

CPC International operates four wet milling plants in the United States. Two of these pay for treatment of their wastes in municipal treatment plants. In the past, the other two discharged waste directly to waterways. As awareness of the environmental effects of direct discharge increased, it became evident that this practice could not continue.

A consulting engineering company was retained to make a waste survey at one of our plants, in order to determine the requirements to meet existing effluent standards. The consultants prepared a preliminary biological treatment design, based on their experience with industrial wastes, and the results of the survey.

CPC International management was concerned about the risk involved in installing a treatment process with no experimental data to support the design. It was felt that maximum treatment efficiency would result if specific treatment data were obtained for the waste stream.

The waste summary also indicated that manufacturing process improvements might significantly reduce the waste load to be treated. Therefore, it was decided to study the treatability of the waste stream, and at the same time to conduct a vigorous waste load reduction program. The waste load reduction was an important and integral part of the over-all pollution abatement program. BOD of the waste stream was reduced to about one-half of its original value by isolating sanitary wastes and sending them to the municipal treatment plant; by installation of new process control instruments in critical areas; by operator and supervisor training regarding process losses, supported by an extensive waste stream monitoring system; and by abandoning an intermittently operated process which generated a significant waste load.

TREATABILITY STUDIES

It was expected that the carbohydrates and volatiles in the waste stream would be readily biodegradable. Therefore, the experimental program was limited to study of the biological treatment process. The biological process utilizes a mixed bacterial culture in contact with the waste stream, to convert soluble organics to insoluble bacterial cells.

Numerous variations of the biological process have been developed. Our consultant recommended that the experimental program be limited to evaluation of aerobic processes.

The experimental work was conducted under the guidance first of A. W. Busch (then at Rice University), and later W. B. Davis (formerly at Texas A & M University).

It was decided to study two variations of the aerobic biological process. One was an aerated lagoon and settling process, which is simply a lagoon where oxygen is supplied to the mixture of waste and culture, followed by a quiescent pond where the biomass is allowed to settle. No biomass is recycled to the aeration tank. This method of treatment has been used by one wet milling company, and was described by McIntosh and McGeorge.(6) This process requires very little operator attention, but has the disadvantage that there are no operating controls to compensate for variations in waste characteristics or concentration. A large land area is also required.

The other system studied was the completely mixed activated sludge process. This consists of an aeration tank, usually followed by a gravity clarifier. Biomass concentration in the aeration tank can be controlled by recycling clarifier underflow. The advantage of this method of treatment is that operating conditions can be controlled by adjusting the biomass recycle rate.

EXPERIMENTAL RESULTS - AERATED LAGOON

The aerated lagoon process was studied on a pilot plant scale. The aeration tank volume was 35,000 gallons, equipped with a 5-hp surface aerator. The settling pond was about the same size.

It was found that a satisfactory effluent could be obtained at retention times as low as 4 days. Satisfactory biomass separation was obtained in the settling pond, although occasionally in warm weather clumps of sludge floated to the surface.

Projections of the size of the full scale treatment process showed that sufficient land was not available at the plant site. Since no land was available adjacent to the plant site, an expensive pumping and piping system would have been required. As a result, it was decided that the activated sludge process would be the most economical for this location.

EXPERIMENTAL RESULTS - ACTIVATED SLUDGE

Activated sludge treatment was evaluated on a laboratory scale using techniques described by A. W. Busch.(7) The equipment is diagrammed in Figure 2. The laboratory reactor studies were designed to develop a culture acclimated to the waste under continuous flow conditions. After several weeks of continuous operation at the selected conditions, the capacity of the culture for removal of soluble COD from the waste was determined by a batch test as described by Busch.(7)

The batch test consists of aerating a mixture of waste and acclimated culture. Samples are taken frequently during the test, and analyzed for soluble COD and suspended solids. The results are plotted as shown in Figure 3. The slope of the COD depletion curve, and corresponding values of suspended solids, are used to prepare a unit rate of removal curve. An example of a unit rate of removal curve is shown in Figure 4. This curve shows the rate of COD removal that can be obtained for any effluent COD. By selecting an MLSS concentration, the aeration tank volume for the desired effluent COD can be calculated. A series of these curves was obtained during the experimental program, and the most conservative values were used for the final design.

Biomass growth rate was estimated by material balance calculations from operation of the continuous laboratory reactors. The growth rate was correlated with food to mass ratio (F/M) as shown in Figure 5.

Oxygen uptake rates were also determined from the continuous reactors. The air supply was shut off, the oxygen depletion measured, and correlated with F/M. These results are shown in Figure 6.

The batch test results, together with the biomass growth rate and oxygen uptake curves, were used to design the aeration tank for the treatment plant.

TREATMENT FACILITIES

The flow diagram of the treatment plant that was designed from the laboratory data is shown in Figure 7. Some of the waste streams are discharged batchwise, so an equalization tank is used to blend out variations in flow, concentration, and pH. The equalization tank also provides some surge capacity for accumulation of the waste in case of equipment failure, and as a source of supply to maintain the culture during weekends, when little waste is discharged from the manufacturing area.

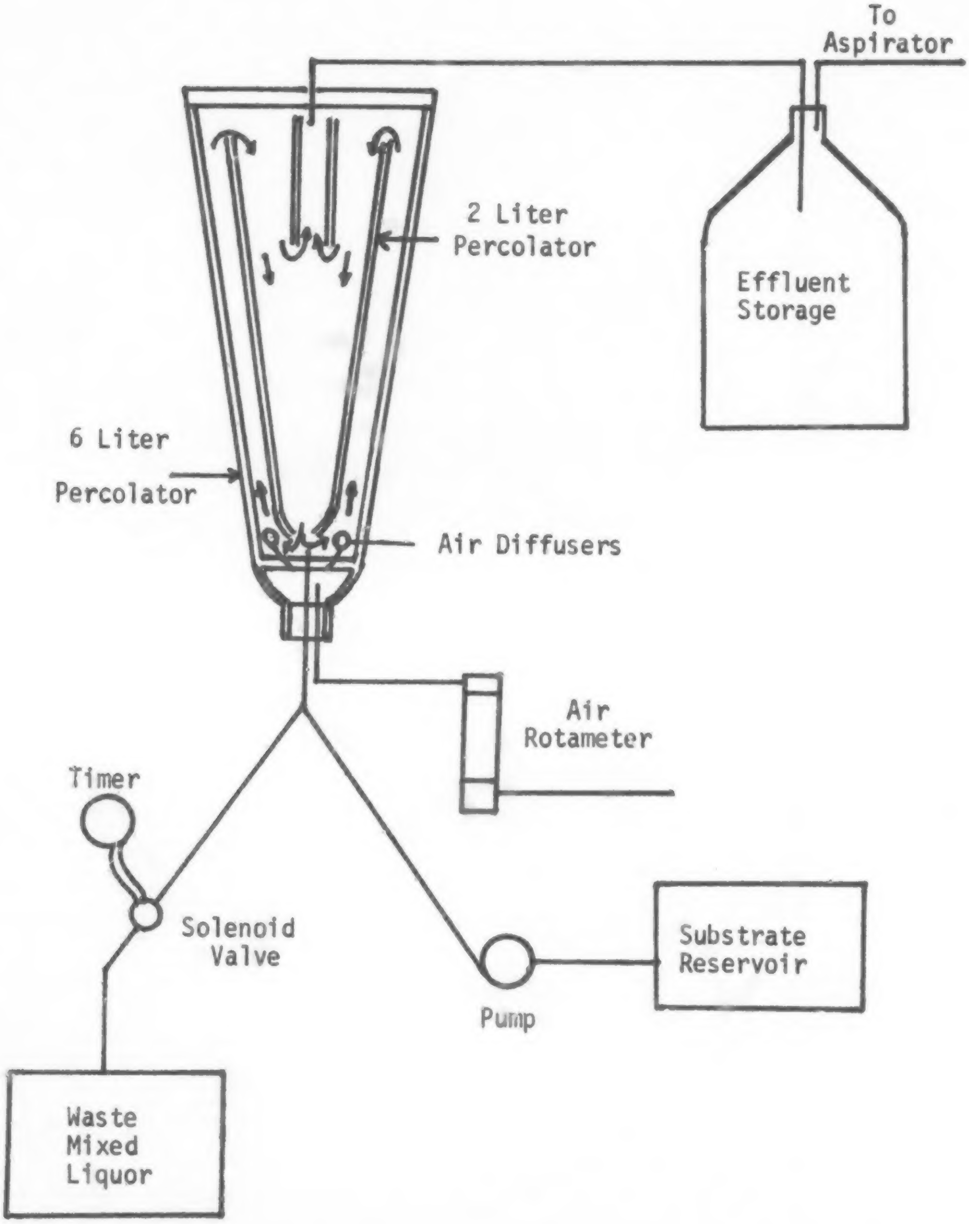
To Aspirator
2 Liter Percolator
Effluent Storage
6 Liter Percolator
Air Diffusers
Air Rotameter
Timer
Solenoid Valve
Substrate Reservoir
Pump
Waste Mixed Liquor

Figure 2. Schematic Drawing of Laboratory Activated Sludge Reactor

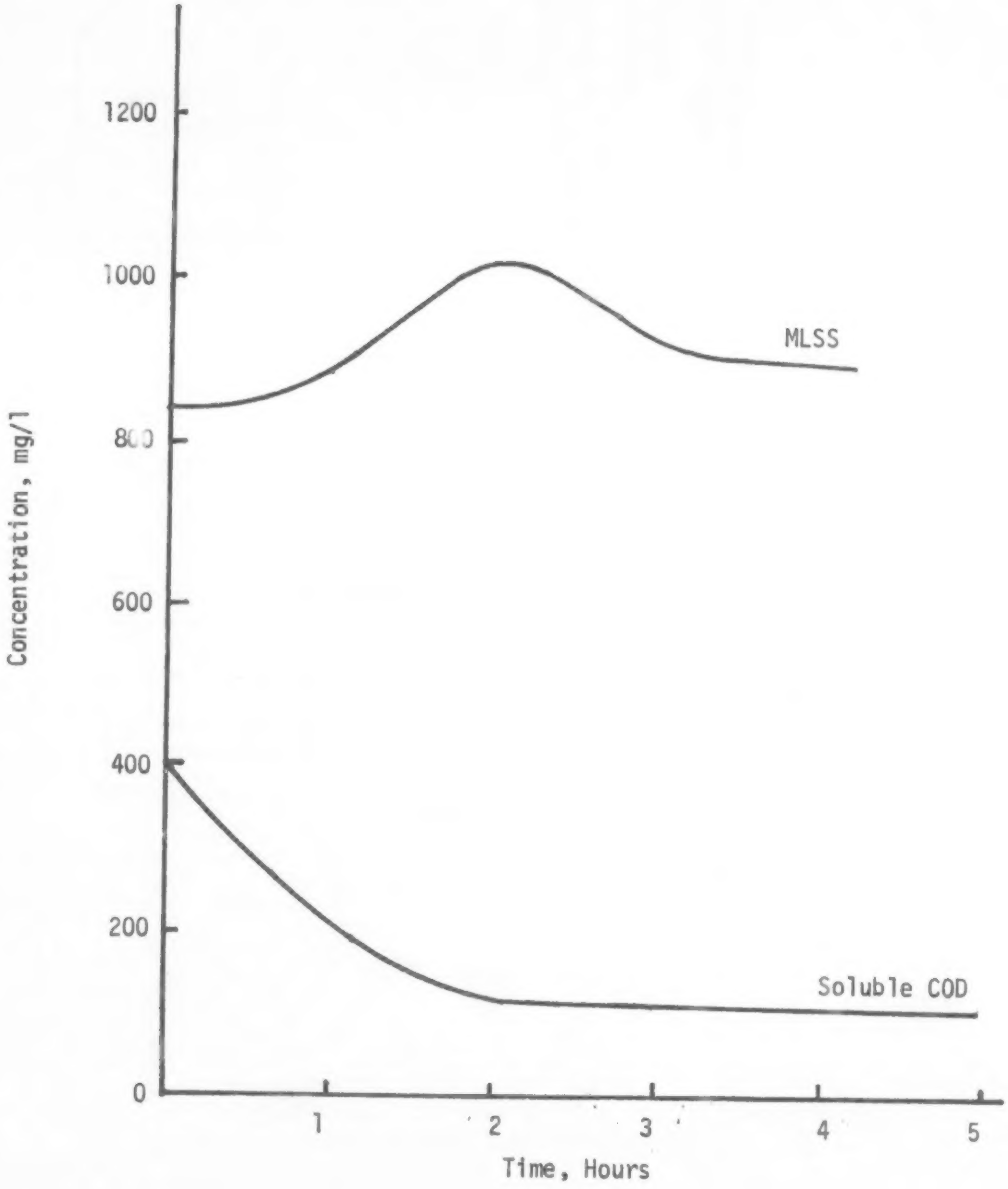

Figure 3. Typical Batch Test Data

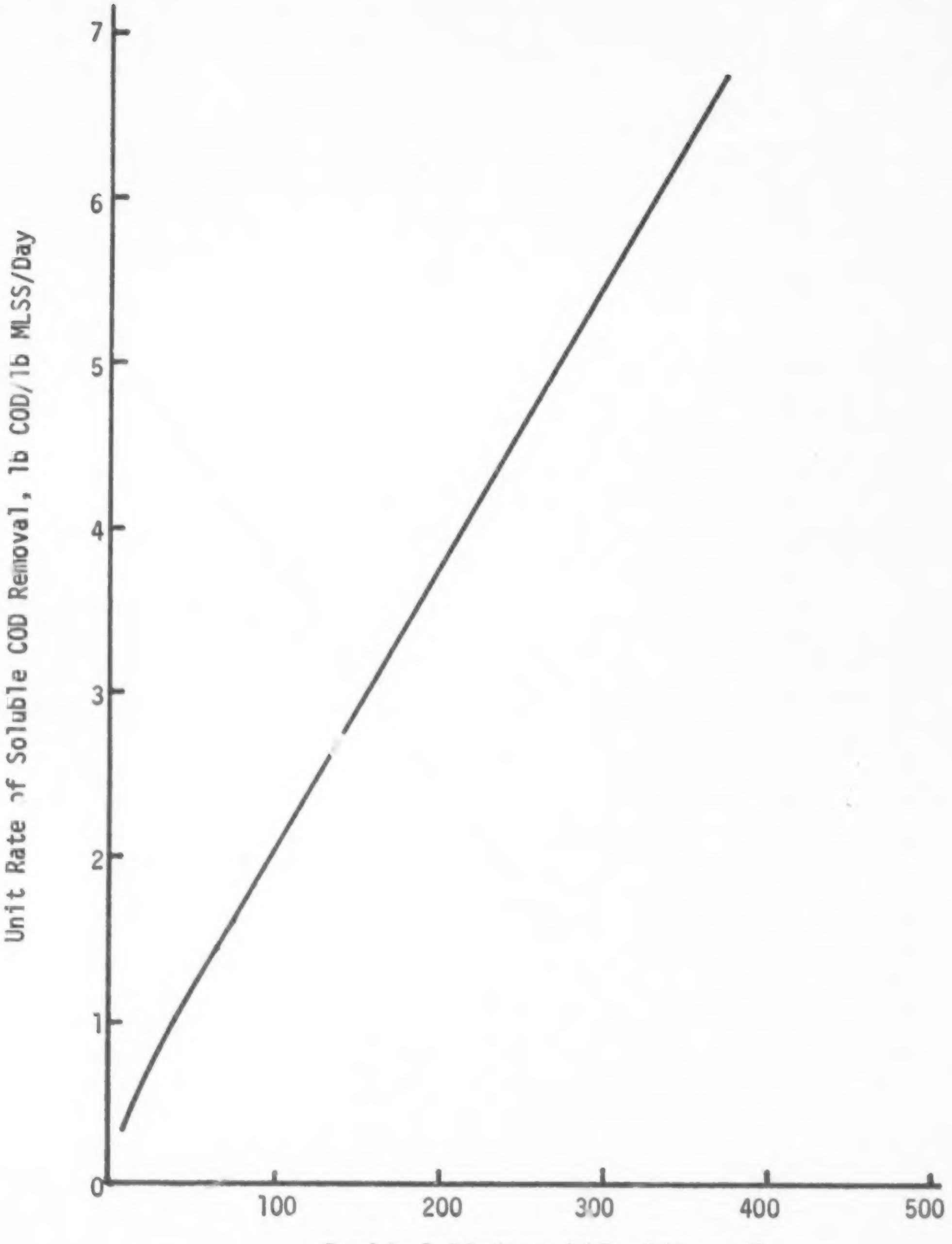

Figure 4. Typical Unit Rate of Removal Curve

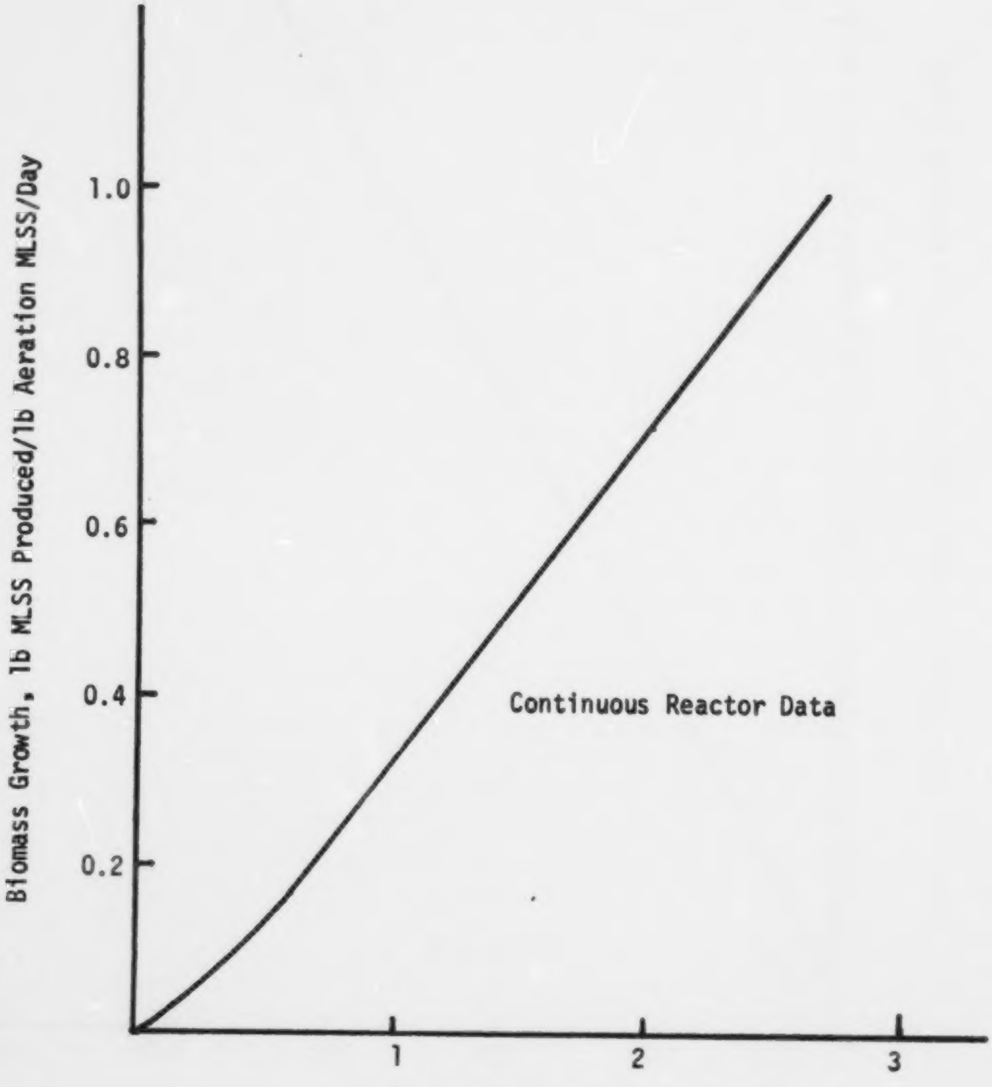

Figure 5. Biomass Growth Rate

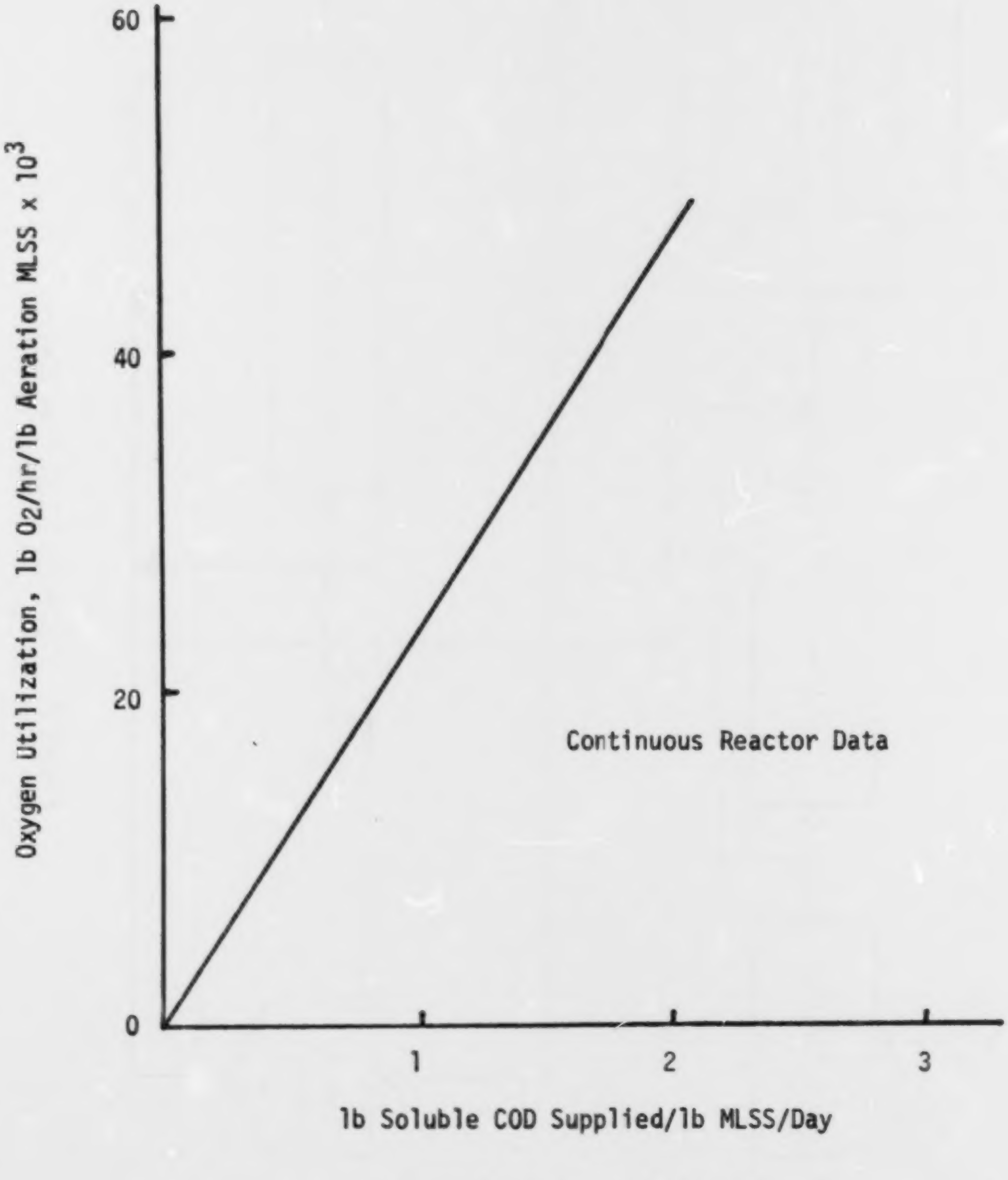

Figure 6. Oxygen Utilization

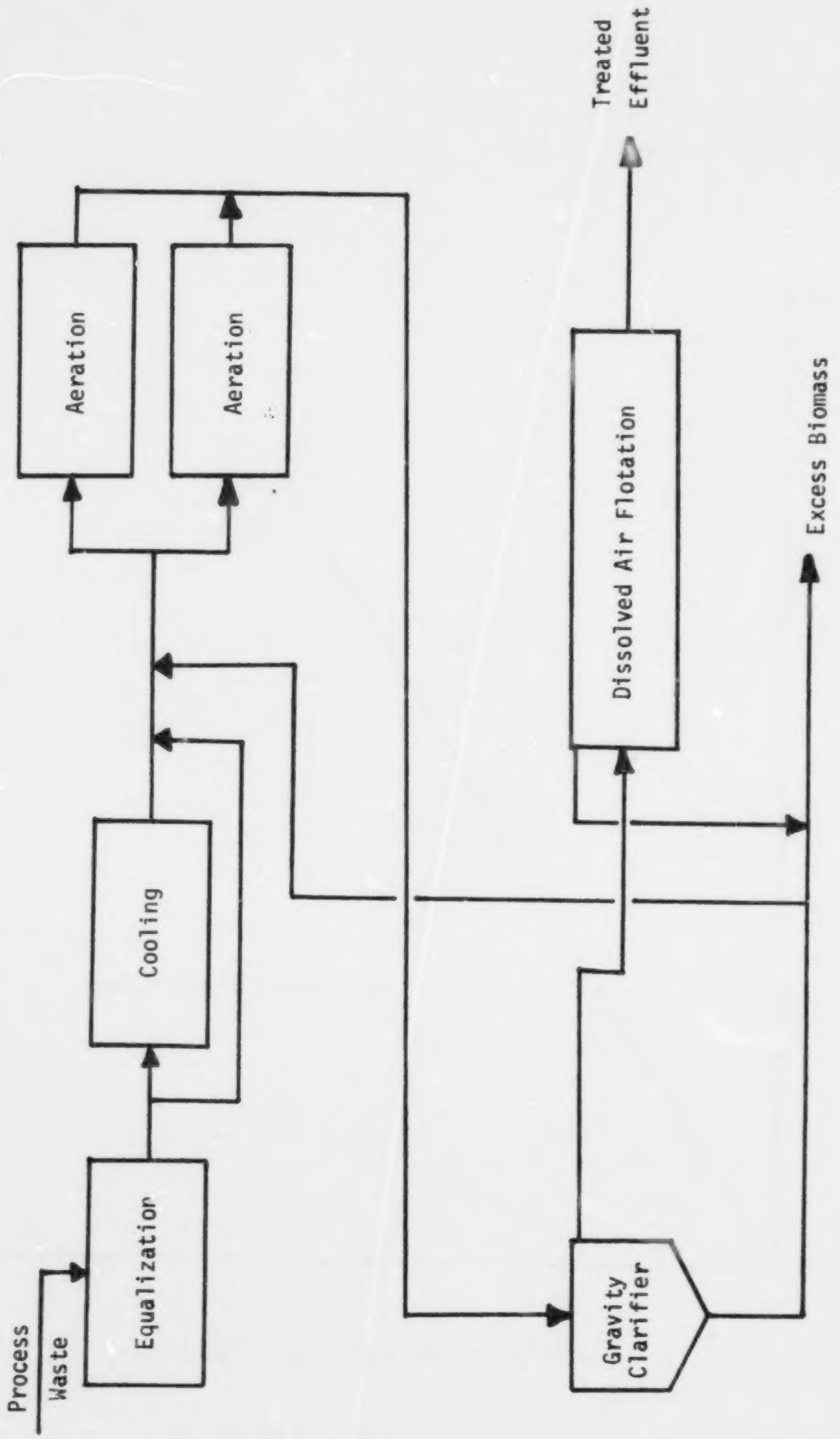
Process Waste
Equalization
Cooling
Aeration
Aeration
Treated Effluent
Dissolved Air Flotation
Excess Biomass
Gravity Clarifier

Figure 7. Treatment Plant Flow Diagram

Flow from the equalization tank goes to two aeration tanks in parallel. The raw waste temperature can get as high as 140°F, so some or all of the aeration tank supply can be directed over a cooling tower, to maintain the design temperature of 75°F in the aeration tanks. Fixed mount surface aerators are used to provide the oxygen.

Effluent from the aeration tanks is pumped to a circular gravity clarifier. Recycle and excess biomass are pumped from the bottom of the clarifier.

Overflow from the clarifier goes to a dissolved air flotation cell, before discharge to the stream.

The treatment plant flow sheet is quite conventional. The difference between this and many other installations is that the process was designed for a specific waste, using relatively new laboratory methods for obtaining the design data for a completely mixed activated sludge process. In recognition of this, the U.S. Environmental Protection agency awarded CPC International a construction and demonstration grant. Certain eligible demonstration costs were funded to a maximum of 70%, together with a fixed amount for construction, based on 10% of the estimated construction cost. The maximum award was equivalent to about 27% of the total eligible estimated construction and demonstration costs. In plant sewer changes, development work and biomass disposal facilities were not part of eligible costs.

TREATMENT PLANT OPERATING RESULTS

The treatment plant has been in full operation for about 6 months. The results have shown that the rate of soluble COD removal closely matches that predicted by the laboratory tests. Oxygen uptake also was closely predicted. Positive dissolved oxygen concentrations are maintained up to the maximum design loading of the treatment plant. Excess biomass production is also within the range predicted.

A major difference between laboratory and full scale performance has been in the physical characteristics of the biomass. During operation of the laboratory reactors, growth of filamentous organisms was a frequent problem. It was because of this that the flotation cell was included in the treatment. It had been found during the laboratory studies that the filamentous growth could be separated by dissolved air flotation.

In the full scale plant, filamentous growth has not occurred. However, a continuing problem has been a dispersed growth, which results in excessive suspended solids in the effluent. While most of the biomass forms a floc with fairly good settling characteristics, a fraction of the growth remains suspended as individual bacteria. The particles are too small to be removed in the dissolved air flotation cell without the use of a chemical flocculating agent.

The high suspended solids level in the treated effluent not only results in failure to meet the suspended solids criteria, but also causes a high BOD due to the oxygen demand of suspended bacteria.

There has been a continuing program to determine the cause of the dispersed growth. Variables that have been or are being studied include stability of waste load and pH, effect of F/M ratio, factors affecting the growth of protozca, which have generally been lacking in this system, and the effect of ammonia nitrogen concentration. The results of this work will be included in the project report that will be prepared upon completion of the demonstration grant program.

SUMMARY

During many years of development of the corn wet milling process, product losses to liquid effluent streams were greatly reduced by recycling process waters, and recovering solubles as a by-product.

As the need for additional improvement in effluent quality became known, product losses were further reduced by process modifications.

Laboratory treatability studies were used to determine the requirements for treatment of the remaining waste by the completely mixed activated sludge process. Good agreement was obtained between laboratory and full scale operation with respect to rate of soluble COD removal, oxygen requirements, and biomass growth rate. Physical characteristics of the biomass differed between the laboratory and full scale processes. Filamentous growth was a major problem in the laboratory, while dispersed individual bacteria has been a continuing problem in the full scale plant. This has resulted in failure to meet the design effluent suspended solids and BOD concentrations. A program to determine the cause of this problem is still in progress.

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SEPARATION, DEWATERING AND DISPOSAL OF SUGARBEET TRANSPORT WATER SOLIDS***

by

I. V. Fordyce* and A. M. Cooley**

INTRODUCTION

Beet sugar factories are large users of water and the treatment of this water before disposal as waste water is a problem which affects the entire economics of sugar processing. It is necessary then to develop methods which will permit satisfactory reuse of the water with minimum amounts accumulated for treatment and disposal to receiving streams.

The process stream accounting for the largest amount of both water and solids is beet washing and transport water. This stream is reported by Fischer and Hungerford (1) to contain the dirt tare averaging 5 to 6% of the beet weight. The fluid ranged from 1,200 to 4,000 gallons per ton of beets sliced with an average of 2,340 for 58 factories included in their survey.

The transport water in most factories is recycled after separation of much of the suspended solids. The water in the system at Crookston, Minnesota was approximately 700,000 gallons and the total circulated per day about 8 million gallons.

In the present study the wash stream was screened over .054 inch slotted vibrating screens and the settleable solids separated in a 115 ft. diameter by 8 ft. SWD clarifier. The overflow returned directly to the beet flume and the underflow was pumped to mud ponds for further settling and accumulation of solids. The pH was adjusted to a high level in the flume water by the use of slacked lime as a flocculating aid, and to minimize bacterial growth.

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* Research Chemist, American Crystal Sugar Company, East Grand Forks, Minnesota

** Professor of Chemical Engineering, University of North Dakota, Grand Forks, North Dakota

*** This investigation was supported in part by funds from the Environmental Protection Agency, Water Quality Office, under Grant No. 12060 ESC, and American Crystal Sugar Company, Denver, Colorado, and conducted at their Crookston, Minnesota plant

The underflow mud, in fluid condition, deposited in a settling pond becomes septic as the organic matter is decomposed and stabilized under the anaerobic conditions which exist, and odors develop.

OBJECTIVES

The objectives of this study were:

A: Optimum clarifier operation when wash and flume water were recycled.

B: Filtration characteristics of the underflow stream from the clarifier.

C: Odor control in the filtered cake from the underflow stream.

METHODS AND MATERIALS

Phase I of this project consisted in determining sizing and operational parameters using an Enviroclear 3 ft. dia. pilot model clarifier for additional thickening of the underflow from the main clarifier and filtering the slurry in pilot model filters. Three types of pilot model filters were tested: (a)- continuous 3 ft. dia. x 1 ft. face Eimcobelt vacuum filter; (b)- 3 ft. dia. x 1 ft. face Eimco precoat rotary vacuum filter and (c)- an Industrial Filter and Pump Mfg. Co. pressure leaf filter Model 112 BMD, Series R-80. Filtration characteristics were studied with a bench scale 1/10 sq. ft. test leaf vacuum filter prior to pilot unit studies.

The data from Phase I were to be directed toward sizing and choice of equipment for filtration of the complete underflow from the clarifier and satisfactory disposal of the filter cake in Phase II.

The conventional mud settling ponds would not be needed if the clarifier underflow were filtered and very little waste water would have to be impounded with its odor problems and problems of stabilization to an acceptable B.O.D. for discharge into a receiving stream.

EXPERIMENTAL

Clarification

The treatment of flume water for clarification is complicated by the fact that the volume rate of recycling varies with the addition of condenser water to this stream. In addition the suspended solids content depends upon soil conditions during harvesting of the beets and while the beet tare, as stated earlier, averages 5 to 6 percent of the weight of the beet, it may range from less than 3% to more than 10%. The pH of the flume water is controlled by the use of lime but under certain conditions when the organic content of the flume water builds up bacterial action may dominate and the flume water becomes acid with a slime forming growth. Under these conditions paraformaldehyde or other bactericide may be necessary for recovery of alkaline conditions with lime.

Temperature in the fluming system is usually a compromise between that which does not permit rapid bacterial growth and that which will allow handling and thawing of frozen beets.

The treatment of water to the clarifier in this study consisted in control of pH with lime, and the addition of the waste lime from the juice purification processing step. Some uncontrolled variables complicated clarifier action and could not be predicted. These consisted in accumulation of rather large amounts of beet fragments when frozen beets were handled and possible deflocculation of solids due to the inadvertant addition of phosphate during boiler blow down.

The operation of the main clarifier in terms of quality of the flow to the clarifier and the quantity of the overflow and underflow for a period of 36 days is given in Table 1.

The biochemical oxygen demand with some variations due to processing of frozen beets reached a level and remained rather constant. This has been the experience of others as reported by Blankenbach and Willison (2).

The solids content of the underflow in most cases was too low for satisfactory cake formation in a vacuum type filter and further thickening was necessary.

The low solids content was not the result of lack of capacity of the main clarifier but was a result of operation. Additional water entered the system as condenser water and a like volume had to be discharged from the cycle. This was discharged as underflow from the thickener. Clarified overflow could have been discharged and this would have resulted in a greater solids content in the underflow. The location of valves at some distance from the clarifier made it difficult to remove excess process water except as underflow stream.

A comparison of settling rates of several polyelectrolytes was made by jar studies at different polymer concentrations by measurement of concentrated solids volume at different time intervals as shown in Table 2. The polyelectrolyte was added to 500 ml. portions of transport water, stirred, and poured into a 500 ml. graduated cylinder, and the volume of settled solids was read at timed intervals. The clarity of the supernatant was about equal for the different polyelectrolytes. Those with the poorer settling rates had poorer clarity.

Table 1. Solids Concentrations in Main Clarifier

	Feed to Clarifier					Clarifier Overflow		Clarifier Underflow
Date	pH	Settleable Solids ml/1	Suspended Solids ppm	Filterable Solids ppm	BOD ppm	Suspended Solids ppm	BOD ppm	Percent Solids
Nov. 15	6.5	27	640			416		8.2
Nov. 16	6.5	33	1208			544		10.5
Nov. 17	7.6	2	676			228		9.0
Nov. 18	7.3	11	1416			540		8.5
Nov. 22	5.7	30	1552	13106			12900	
Nov. 23	5.3	60	556	12548	9600	596		11.4
Nov. 24	6.1	38	268	12584		480		15.8
Nov. 25	6.3	17	316	12570		300		11.0
Nov. 29	6.4	30	632			168		10.9
Nov. 30	6.8	75	524	24340		244		14.0
Dec. 1	6.5	15	654		9600	200	8500	
Dec. 2	8.0	33	592	3500		184		
Dec. 6	11.9	15	436			342		8.0
Dec. 7	12.0	16	504		10500	240	7500	5.5
Dec. 8	11.4	17	846			366		6.0
Dec. 9	11.6	15	1124	1728	11400	556	8100	7.0
Dec. 13	11.8	10	474			332		
Dec. 14	11.8	30	688			472		
Dec. 15	11.4	20	168	3654	9000	496	9200	
Dec. 16	11.4	17	668	4540	12200	616	10900	3.8
Dec. 20	11.4		512		6500		7250	6.8
Dec. 21	11.6	20	508	964	8300	404	6900	6.7
Dec. 22	11.8	21	488	4421	6900	522	6650	4.0
Dec. 23	11.3	16	696	1976		408		6.0
Dec. 27	11.1	10	1288	3116		576		5.1
Dec. 28	11.5	12	808	2989	5250	460	5850	7.5
Dec. 29	11.8	10	988	1691	6200	552	5700	4.2
Dec. 30	11.4	4	876	1684	9150	584	8250	6.0
Jan. 3	11.2	5	1368	2104		472		8.0
Jan. 4	11.2	17	1008	3420	8100	652	6000	5.5
Jan. 5	11.6	8	816	1904	9150	688	8850	4.8
Jan. 6	11.1	10	1132	2263	6310	832	7500	3.2
Jan. 10	11.4	12	1156	2144		668		5.8
Jan. 11	9.5	3	1360	2852		616		4.6
Jan. 12	11.8	10	1240	1328	6900	584	6600	5.2
Jan. 13	11.2	15	816	804	8550	436	8700	4.5

Table 2. Settling Rates of Polyelectrolytes

Poly. Conc.	Settled Solids in ml./500 ml.								
	.5 ppm (1)			1 ppm (2)			2 ppm (3)		
Settling Time (Min.)	2	5	10	2	5	10	2	5	10
Nalco 674	70	50	45	55	45	40	110	70	62
Nalco 7460	65	47	42	40	35	35	110	70	62
Nalco ID 16-71	150	47	42	40	35	27	100	65	57
Betz 1420	62	45	40	30	30	30	75	55	50
Zuclar 110	450	62	50	60	45	42	90	65	55
Nalco 607	490	70	60	325	70	55	475	120	87

(1) 1.5% Solids at 8.7 pH
(2) 2.8% Solids at 9.9 pH
(3) 1.4% Solids at 9.9 pH

A comparison of solids concentration in the underflow and clarity of the overflow in the Enviroclear pilot thickener was made for three polyelectrolytes at two concentrations with results as shown in Table 3. The feed to the Enviroclear for this comparison was screened transport water with main clarifier underflow makeup to provide a uniform feed rate of 15 gal. per minute to the Enviroclear thickener at a pH of 11.4 without additional slacked lime addition. The retention time in the Enviroclear was 10 minutes.

Table 3. Polyelectrolyte Comparison

Poly.	ppm	Underflow Percent Solids	Overflow Sus. Solids ppm
Betz 1420	3	18.2	248
	5	29.0	136
Nalco 41A06	3	16.6	182
	5	20.2	188
Betz 1260	5	15.8	186

Lab. Test Leaf Filtration Studies

Laboratory filtration tests were done using a 1/10 square foot filter leaf connected through a receiving flask to vacuum. The vacuum could be adjusted to a maximum of about 20 inches of mercury. The feed slurry, contained in a pail equipped with a stirrer, was heated to the desired temperature and the leaf inserted for two minutes of cake build up.

The laboratory bench scale tests were done early in the season before any bacterial growth appeared. The tests reflect characteristics of a suspended solids content uncomplicated by bacterial slimes. The pH could be controlled with reasonable amounts of lime and flocculation could be achieved at the controlled pH with reasonable amounts of polyelectrolytes. The physical characteristics of the underflow from the clarifier determined that the solids content was very critical in filter cake formation and that rapid settling of part of the inorganic solids left a liquid suspension which would not form a satisfactory cake.

A sample of slurry from the underflow of the large clarifier was wet screened and the minus 200 mesh material was sized by ASTM hydrometer method 422 (3).

The fractions above 200 mesh were collected, dried and weighed. The material above 48 mesh was mostly beet fragments and while this was only about 3.2% of the total weight of solids, its bulk was very high in proportion to the high density inorganic solids. Screen analysis of the plus 200 mesh fraction is shown in Table 4.

Table 4. Screen Analysis of Underflow Mud from Clarifier Collected January 25, 1972

Tyler Mesh	Percent
+20	1.9
-20 +35	.4
-35 +48	.9
-48 +65	.6
-65 +100	1.5
-100 +150	1.3
-150 +200	2.6
-200	90.8

Table 5 shows the size distribution of the minus 200 mesh mud.

Table 5. Size Distribution of -200 Mesh Fraction by Hydrometer ASTM Test Method 422

Size Microns	Percent
Less than 1	20
1-2.5	3.5
2.5-3	1
3-5	5.5
5-10	15
10-20	16
20-30	10
30-74	29

The hydrometer test was done after deflocculating the mud with hexametaphosphate.

A sample with no deflocculant settled to a relatively clear top liquid within 30 minutes but after addition of the deflocculant there was no clear top fluid after 24 hours. The particle size analysis shows the ultimate particle size but not the flocculated aggregate in the feed to the filter.

In order to build up the solids content of the slurry feed to the filter, dry lime cake from refuse disposal piles was reconstituted and was used as a means of slowing the settling rate of the sand fractions and as a filter aid. The effect of solids rate is shown in Fig. 1. The solids added were of such fine particle size that they aided filtration mainly by keeping the coarser sand fractions in suspension and thus formed a more permeable and firm cake. Pilot runs later with the belt filter gave good filtration rates without the use of reconstituted lime mud if the solids were concentrated properly in the thickener.

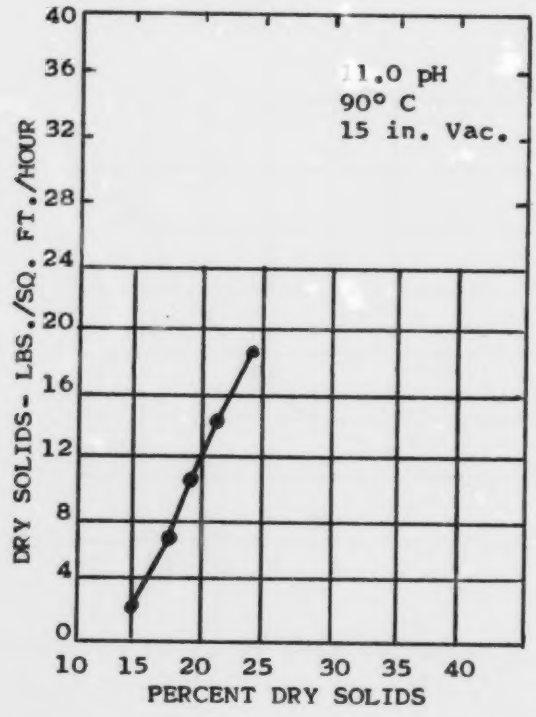

Fig. 1. Filtration Rate vs % Solids in Filter Feed

The addition of slacked lime to control pH had a very great effect on the rates of filtration. In this series of experiments the alkaline underflow from the clarifier was brought down to a pH of 5.5 by the addition of acetic acid and then adjusted to increasing pH values by addition of calcium hydroxide. The amount of calcium hydroxide necessary for pH adjustment was insufficient to affect the solids content of the slurry appreciably. Increased addition of lime as indicated by higher pH values increased the filtration rate very markedly as shown in Fig. 2.

A reserve of calcium hydroxide as indicated by high pH was necessary for good filtration. Slurries with pH near normal were difficult to filter.

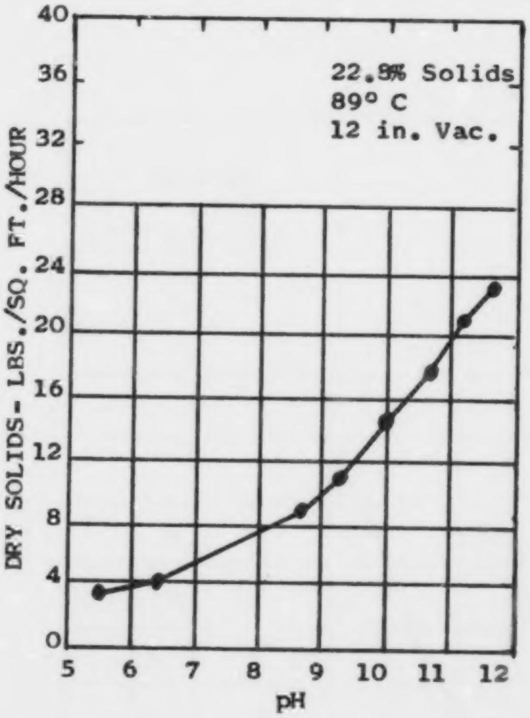

Fig. 2. Filtration Rate vs pH of Filter Feed

The effect of temperature on the rate of filtration at two pH values are shown in Fig. 3 for a solids content feed of 25.85 and 34.5%. Increase in temperature resulted in an increased rate of filtration and again the higher rate of filtration was at the higher pH value.

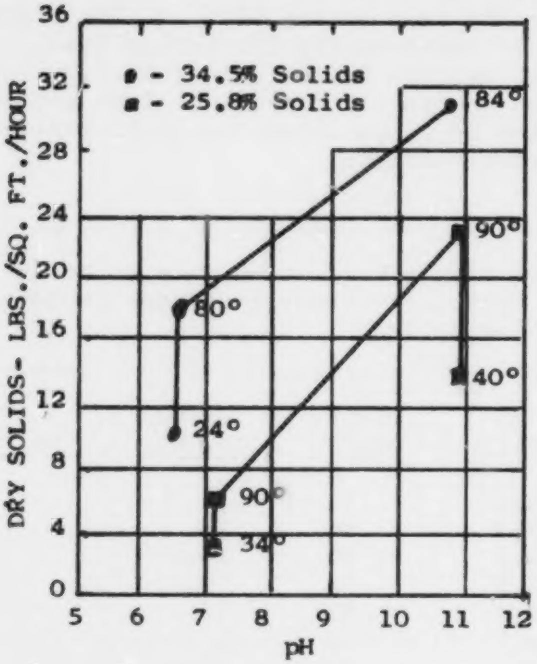

Fig. 3. Filtration Rate vs pH and Temp.

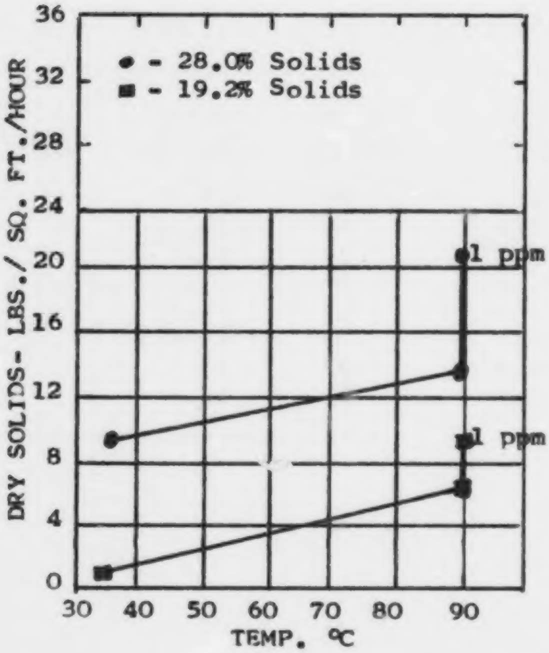

Fig. 4. Effect of Heat and Polyelectrolyte on Filtration Rate

Fig. 4 shows the effect of temperature and polyelectrolyte on the rate of filtration at two pH values at a solids content of 28% and 19.2% for the feed to the filter. The higher temperature and pH values again improved the filtration rate. The pH adjustment was made with calcium hydroxide and the increased filtration rate may have been due to the effects of lime rather than pH as such. The addition of 1 ppm anionic polyelectrolyte further increased the filtration rate.

Table 6. Data for Fig. 1. Filtration Rate vs Percent Solids in Filter Feed. (Increase in Solids Content from Dry Waste Lime Solids)

pH	Feed % Solids	Temp. Deg. C	Vacuum In. Hg.	Dry Cake Lbs./Sq. Ft./Hr.
11.0	15.0	92	15	2.1
11.0	17.3	90	15	6.7
11.0	19.5	90	15.5	10.4
11.0	21.5	94	16	13.8
11.0	23.5	90	16	18.4
11.0	23.5	76	15.5	18.8
11.0	23.5	61	15.5	16.3
11.0	23.5	45	15	<1

Table 7. Data for Fig. 2. Filtration Rate vs pH of Filter Feed

pH	Feed % Solids	Temp. Deg. C	Vacuum In. Hg.	Dry Cake Lbs./Sq. Ft./Hr.
5.5	22.8	88	13	3.8
6.5	22.8	90	12	4.1
8.7	22.8	89	11.5	8.7
9.4	22.8	89	11.5	10.7
10.0	22.8	89	11.5	14.6
10.8	22.8	89	12.5	17.8
11.2	22.8	92	13	21.2
11.7	22.8	89	13	23.4

Table 8. Data for Fig. 3. Filtration Rate vs pH and Temperature

pH	Feed % Solids	Temp. Deg. C	Vacuum In. Hg.	Dry Cake Lbs./Sq. Ft./Hr.
6.6	34.5	24	15	9.8
6.6	34.5	80	12	18.2
10.9	34.5	84	13	30.9
7.2	25.8	34	13	3.2
7.2	25.8	90	14.5	5.2
11.0	25.8	90	14	23.8
11.0	25.8	40	15	13.7

Table 9. Data for Fig. 4. Effect of Heat and Polyelectrolyte on Filtration Rate

pH	Feed % Solids	Temp. Deg. C	Polyelectrolyte ppm	Vacuum In. Hg.	Dry Cake Lbs./Sq. Ft./Hr.
10.5	28.0	35	0	16	9.5
10.5	28.0	90	0	15	14.4
10.5	28.0	90	1	16	20.7
9.5	19.2	32	0	14.5	1.6
9.5	19.2	90	0	14.5	7.7
9.5	19.2	90	1	12.5	9.9

Pilot Filtration

An Eimcobelt filter 3 feet in diameter by 1 foot wide was leased and a series of 89 runs were made covering 18 days of plant operation.

The feed to the filter came directly from the underflow of the 115 foot main clarifier with the provision also that this underflow could be thickened further in a pilot model Enviroclear thickener. A heating tank was installed between the thickener and the filter and chemical treatment or addition of filter aids could be done in this heating tank, which was equipped with an agitator.

To begin the study of the effects of certain variables on the rate of filtration a number of conditions set definite limits on many of the variables.

In the recycling of transport water organic matter builds up to levels favorable for bacterial growth. In order to keep bacterial growth under control slacked lime was added to maintain high pH. When the pH did lower unavoidably because of bacterial growth the slime formation adversely affected the filtration rate. Other variables interacted at times so that it was difficult to separate cause from effect.

Easily filtered material also dried quickly in the dewatering segment of the filter and cracked to such an extent that high vacuum could not be maintained. The vacuum for best cake pickup sometimes was at the lowest vacuum. The vacuum pump was a wet type pump and the supply of water to the location housing the filter was through a single pipeline. The supply could be either hot or cold. It was found that hot water was desirable for cleaning the filter belt after discharge of the cake but if this water were used through the vacuum pump the vacuum was several inches less than when cold water was used.

It would appear from the data presented and comparing leaf data with rates of filtration on the belt filter that the leaf filter was much more effective in terms of pounds of dry solids per hour square foot. The data for the belt filter was calculated on the basis of total drum area rather than area submerged and consequently is about 1/3 less than it would be if calculated on the basis of area forming cake. The rates of filtration in the two types of equipment were roughly equivalent when calculated on effective filter area.

Pilot filtration runs using the Eimcobelt filter were made on:

A: Main clarifier underflow with pH adjustment followed by additional thickening in the Enviroclear pilot thickener and temperature adjustment of the final underflow.

B: Main clarifier underflow with pH adjustment followed by additional thickening in the Enviroclear pilot thickener and additional solids added as reconstituted waste lime.

C: Main clarifier underflow with pH adjustment followed by additional thickening in the Enviroclear pilot thickener and additional solids added as lignite fly ash.

D: Main clarifier underflow and additional thickening with the addition of all of the lime cake from juice purification to the main clarifier.

The addition of lime at the rate of 0.31 lbs. per 10 gallons of underflow from the main clarifier to raise pH and additional thickening in the Enviroclear pilot thickener before filtration resulted in satisfactory cake pickup and cake separation from the belt when filtered on the Eimcobelt filter. During the few instances of poor cake pickup it was noticed that temperatures were down and also pH values had decreased. This latter effect was due to a lack of sufficient lime and as in the filtration with the leaf filter lime was observed to be beneficial in filtering with the belt filter. Data for this series is shown in Table 10.

Table 10. Filtration Rates for Vacuum Filtration

Run	pH	Temp. °C	Feed Percent Solids	Vac.	Dry Cake Lbs./Sq. Ft./Hr.	Additions
5	12	82	13.3	11	4.4	None
6	12	60	13.3	10	4.5	"
7	12	62	13.3	9	3.6	"
8	12	78	13.3		3.1	"
9	10.9	90	16.2	9	6.5	"
10	10.9	80	16.2	11	8.5	"
11	10.9	70	16.2	10	6.4	"
12	10.9	57	16.2	16	5.8	"
13	10.9	65	16.2	10	4.4	"
14	10.9	60	16.2	10	4.6	"
18	12.1	85	8.1	8	5.7	"
19	12.1	70		10	6.0	"
20	12.1	95		14	5.4	"
21	12.1	93		15	5.1	"
22	12.1	85		16	5.	"
23	11.8	66	11.2	14	3.6	"
24	11.3	95	15.1	16	7.2	"
25	11.3	70		17	3.5	"
26	9.9	75	18.5	17	2.8	"
27	9.9	95		17	3.7	"
28	9.9	95		18	5.3	"
29	11.8	77	17.6	15	7.1	"
30	11.6	90	20.9	15	11.4	"

The underflow from the main clarifier was run to the Enviroclear thickener and then treated with additional lime solids from dry waste lime cake reconstituted in the underflow to increase the solids content. The pH was controlled by the addition of calcium hydroxide. The cake pickup was variable but, except for the beginning of a day's filtration, was very good. The additional solids increased cake pickup. See Table 11.

Table 11. Filtration Rates with Waste Lime Addition

Run	pH	Temp. °C	Feed Percent Solids	Vac.	Dry Cake Lbs./Sq. Ft./Hr.	Additions
31	10.9	85	19.9	17	4.1	
32	10.1	90	22.2	17½	3.9	10# W.L./40 Gal.
33	11.2	87	28.0	17	6.3	20# " " "
34	11.2	80	29.0	18	5.1	30# " " "
35	12.0	75	17.0	10	11.6	30# " " "
36	12.0	78	17.0	15	6.4	
37	12.1	95	11.0	14½	3.5	20# " " "
38	12.1	95	11.0	14	7.4	10# " " "
38A	12.1	95	11.0	9	6.7	10# " " "
39	10.5	95	11.0	15	2.3	20# " " "
39A		90		16	4.1	
40	12.2	80	20.6	14	11.2	20# " " "
41	12.3	85	17.8	11	10.8	20# " " "
42	12.1	95	13.6	12	9.2	20# " " "
43	12.3	80	19.4	12	10.5	10# " " "
44		90		16	3.4	10# " " "
45		90		17	4.3	10# " " "
46		90		17	8.8	20# " " "
47		95		16	5.1	20# " " "
48	11.6	90	24.6	17½	4.7	10# " " "
49	12.0	95	29.9	17	7.8	20# " " "
50	12.3	95	28	16½	10.1	20# " " "
51		95		16½	9.1	10# " " "
52	12.3	94	25.6	15	9.6	10# " " "

W. L. = Dry Waste Lime Cake

The addition of fly ash after additional thickening of the main clarifier underflow and adjustment of pH with lime was effective as a filter aid although it was not significantly different than equal amounts of reconstituted waste lime filter cake. See Table 12.

The addition of all of the lime filter cake resulting from juice purification to the clarifier and the adjustment of the pH with calcium hydroxide and additional thickening in the Enviroclear resulted in a filter feed which filtered at a higher rate than any other combination. The solid cake was friable and non-sticky and the pickup was much better than that when waste lime or fly ash were used as filter aids. Decreasing the temperature decreased cake pickup of run No. 72. When both the temperature and pH were lowered the cake pickup was very poor. See Table 13.

Table 12. Filtration Rates with Fly Ash Addition

Run	pH	Temp. °C	Feed Percent Solids	Vac.	Dry Cake Lbs./Sq. Ft./Hr.	Additions
53	12.4	95	24.8	16	6.0	10# Fly Ash/40 Gal.
54	12.0	95	24.0	16		10# " " " "
55	12.4	95	24.4	10	10.0	10# " " " "
56	12.4	95	22.5	11	12.6	5# " " " "
57	12.5	95	21.6	16	11.7	2.5# " " " "
58	12.3	95	22.4	17	9.1	None
59		95		16		None
60		95		16½		10# " " " "
61	11.9	95	17.6	14½	4.6	10# " " " "
62	11.7	95	29.0	17½	4.3	10# " " " "
63	11.8	95	26.0	16½	3.2	10# " " " "

Table 13. Filtration Rates with Waste Lime Filter Cake Feed to Main Clarifier

Run	pH	Temp. °C	Feed Percent Solids	Vac.	Dry Cake Lbs./Sq. Ft./Hr.	Additions
68	12.1	95	23.6	14	16.3	Lime Cake to Main Clarifier
69	12.0	90	19.8	11	11.1	"
70	12.1	64	11.6	8½	9.8	"
70A	12.1	40	11.6	10½	8.7	"
71	11.3	30	8.0	8	9.3	"
72	7.0	60			None Collected	"
73	11.4	80	26.0	14	10.8	"
74	11.5	95	21.4	14	12.6	"
75	11.6	87	15.8	16½	9.55	"

Disposal of Filter Cake

Filter cake solids from the pilot filtration studies had moisture content ranging from 39.0 to 50.0%. Three methods of disposal of the filter cake solids are being studied. 1- Sanitary land fill at three foot depth with one foot of earth cover; 2- Windrow distribution on land by dump truck at approximately two foot depth of pile; 3- Spreading on land by dump truck at approximately six inch depth of solids. Decomposition studies will be continued after the spring thaw for decomposition rates and odor production. Preliminary studies in 1971 and unpublished reports indicate that odors from the above methods of solids disposal will be negligible.

SUMMARY

Vacuum filtration of thickened underflow from clarification of beet wash and transport water was accomplished at reasonably high rates by use of an Eimcobelt filter. The solids content of the slurry was important and best results were obtained when solids content in the feed were above 10%, and preferably over 20%.

Addition of calcium hydroxide to pH values of around 11 improved filtration rates and at pH values near 7 there was very little pickup of cake.

When bacterial growth takes place the slurry is very difficult to filter. The recovery of an alkaline pH is difficult to achieve with the use of lime alone but can be accomplished by the use of paraformaldehyde in the transport water at a 0.02% dosage. Lime alone can be used in reasonable amounts for control of pH and bacterial control after formaldehyde has been used as a bactericide.

Both lime cake and fly ash are effective filter aids.

Addition of lime filter cake from juice purification to the clarifier gave an underflow which had the best filtration characteristics of the combinations tried.

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WINERY WASTEWATER TREATMENT***

by

Edwin Haynes*, George Stevens*, and Paul Russell, Jr.**

INTRODUCTION

In 1969 experience with treatment of winery wastewaters in this Country was limited to one winery utilizing aerated lagoons. In California, where the soils and climate are suitable, irrigation and ponding of the wastewaters is used for disposal. In the midwest and eastern areas of the United States, where this technique is not feasible due to climatological hinderances, other techniques must be employed.

In 1969 Widmer's Wine Cellars, Inc. were faced with the problem of providing a very high degree of treatment (96 to 99 percent BOD_5 removal) of their wastewater. Research into literature references failed to reveal any reliable experience to draw upon. Data on treatment of similar industrial wastewaters provided the only basis for planning and design of a suitable Water Pollution Control Plant.

The preliminary proposal for this project included a long-term activated sludge system followed by tertiary sand filter. This system was designed to remove 98% of the BOD_5 from the winery wastewaters. This proposal was accepted by the Widmer's Wine Cellars, Inc. and, with the assistance of a Demonstration Grant from the Environmental Protection Agency, Widmer's undertook construction of the proposed Water Pollution Control Facilities. These facilities were placed in operation in late 1970.

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*Widmer's Wine Cellars, Inc, Naples, New York
**Harnish & Lookup, Associates, Newark, New York
***This project was supported by funds from the Environmental Protection Agency, Project No. 12060 EUZ

Widmer's Wine Cellars, Inc. is located in the Finger Lakes Area of New York State. This area is characterized by steep hills separated by five lakes, all located in a general north-south axis as shown in Figure 1. The climate of this area favors the growth of the characteristic hardy New York State grapes, including principally Concord, Catawba, Niagara, Delaware, Elvira, and Ives. It is said that the frequently severe winters combine with the temperate summer weather to give the New York State wines a very select characteristic flavor.

GENERAL WASTE CHARACTERISTICS

During the fall months, beginning in the middle of September, for a period of four to six weeks, the grapes are harvested and brought to the winery from the vineyards in the valleys and hillsides of the Finger Lakes Area. At the winery the grapes are pressed into juice and stored for later fermentation. During the 1971 pressing season the winery wastewater characteristics were as shown in Table 1 and Figures 2, 3, and 4.

Table 1. 1971 Pressing Season Wastewater Characteristics

BOD_5 Concentration*	1010 mg/l
BOD_5 Discharge	1345 lb/day
Suspended Solids	150 mg/l
Daily Flow	0.16 mgd
pH	7.4 - 7.9
BOD_5 Discharge*	10.6 pounds per ton of grapes pressed
Daily Flow*	1420 gallons per ton of grapes pressed

*90th Percentile Data

In the processing season, when grape juice is fermented into wine and packaged for shipment, the wastewaters have somewhat different characteristics and at Widmer's have been found to be generally as shown in Table 2.

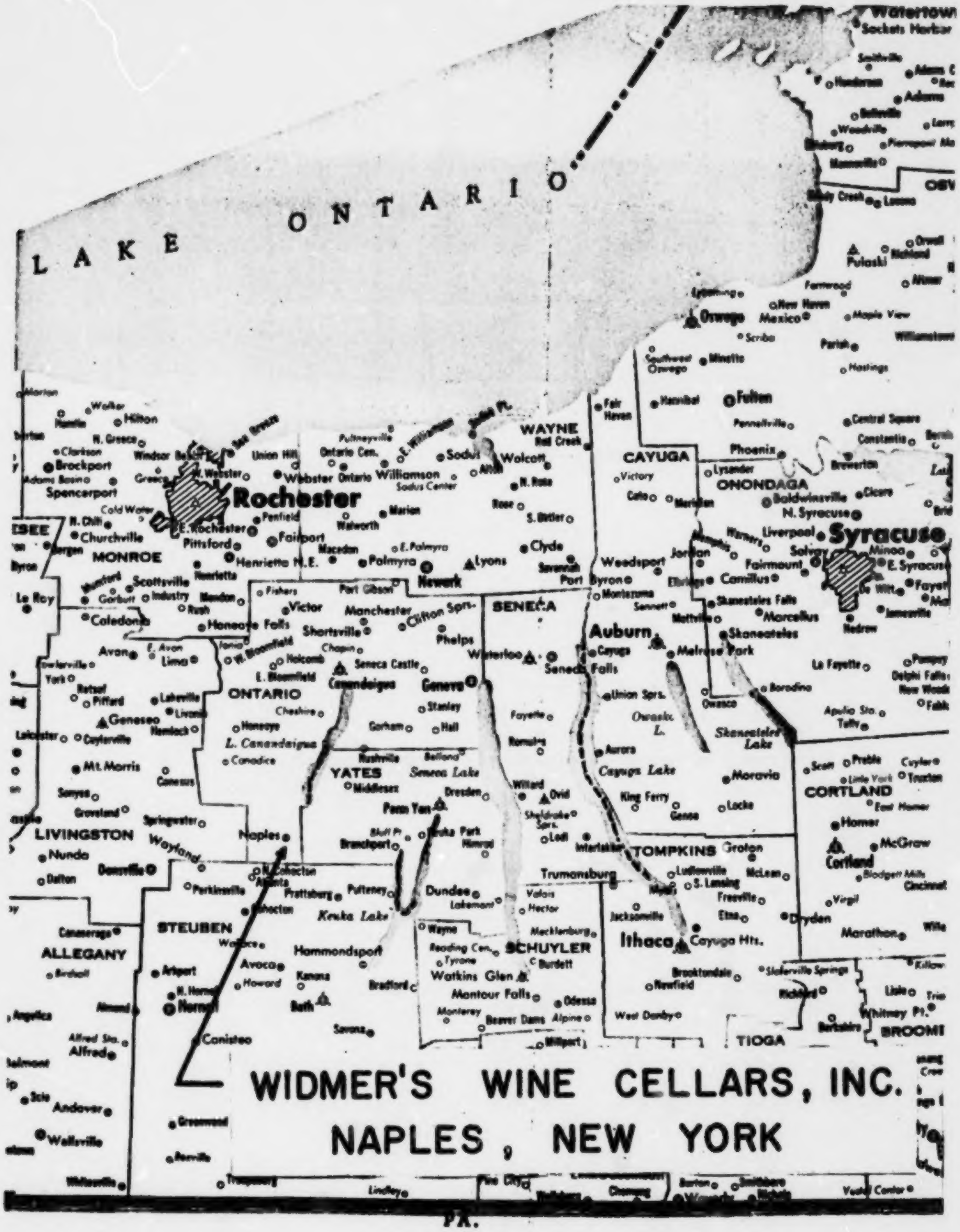
LAKE ONTARIO
WIDMER'S WINE CELLARS, INC.
NAPLES, NEW YORK
Rochester
Syracuse
MONROE
WAYNE
CAYUGA
ONONDAGA
SENECA
ONTARIO
YATES
LIVINGSTON
STEUBEN
ALLEGANY
SCHUYLER
TOMPKINS
CORTLAND
TIOGA
BROOME
Oswego
Fulton
Auburn
Geneva
Canandaigua
Penn Yan
Naples
Ithaca
Cortland
Hornell
Bath
Hammondsport
Watkins Glen
Newark
Lyons
Seneca Falls
Skaneateles
L. Canandaigua
Seneca Lake
Keuka Lake
Cayuga Lake
Owasco L.
Skaneateles Lake
PA.

FIGURE 1

NEW YORK STATE FINGER LAKES AREA

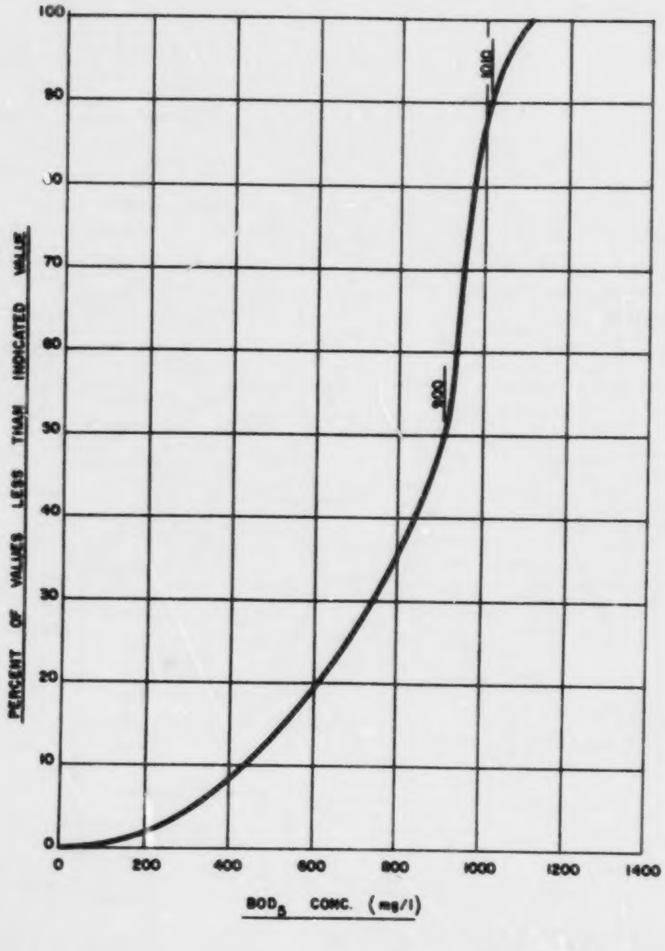

Figure 2

BOD$_5$ CONCENTRATION
PRESSING SEASON WASTEWATER
Widmer's Wine Cellars, Inc.

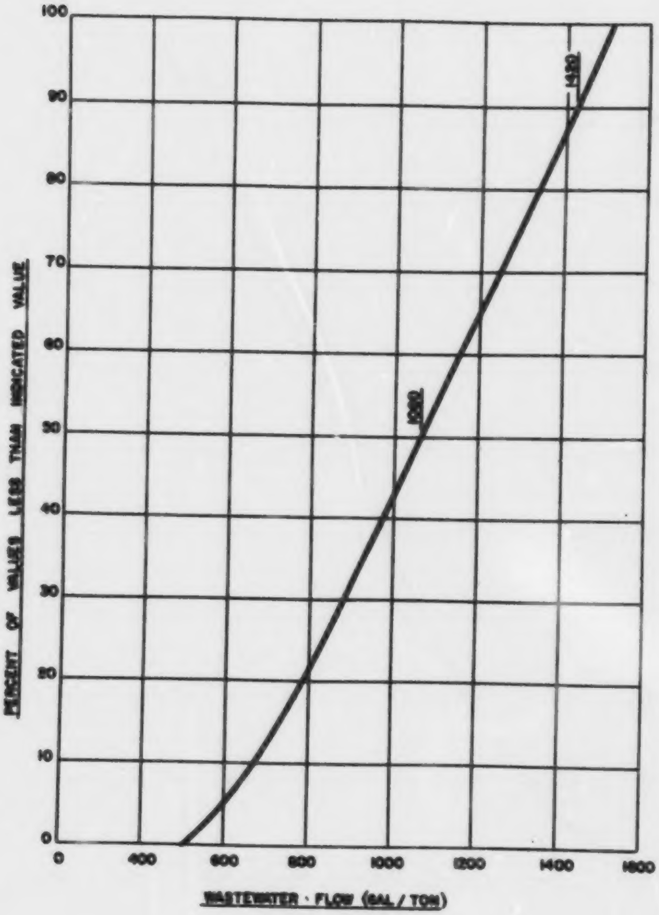

Figure 3

WASTEWATER FLOW
PRESSING SEASON WASTEWATERS
Widmer's Wine Cellars, Inc.

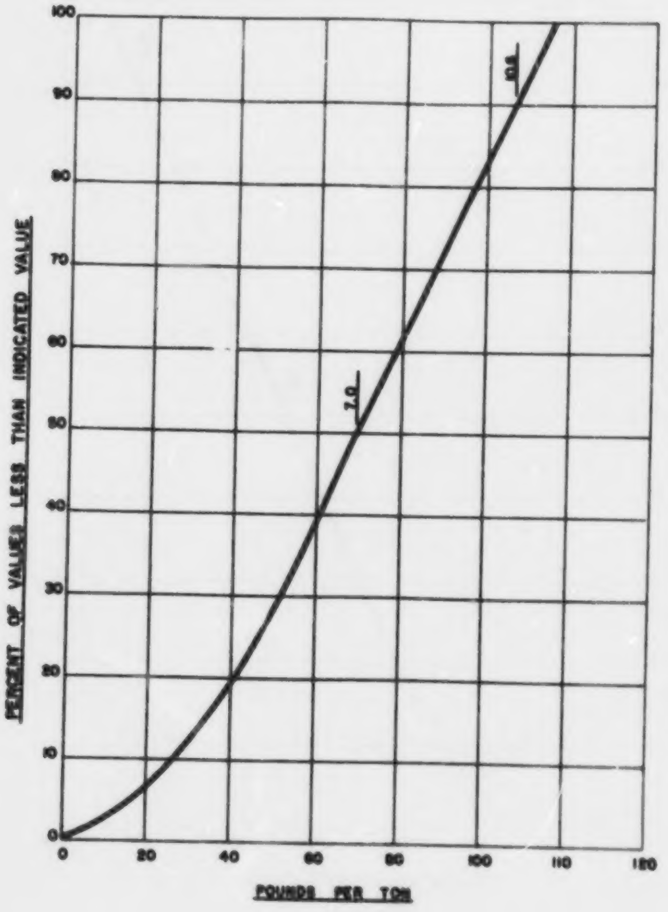

Figure 4

BOD_5 DISCHARGE
PRESSING SEASON WASTEWATER
Widmer's Wine Cellars, Inc.

Table 2. Processing Season Wastewater Characteristics

BOD_5 Concentration*	1370 mg/l
BOD_5 Discharge*	0.57 pounds per case of wine
Daily Flow*	80,000 gallons per day
pH	6.5 - 8.0

*90th Percentile Data

TREATMENT PLANT REQUIREMENTS

In New York State treatment requirements for any water pollution control plant are determined by the ability of the propsoed receiving stream to assimilate the effluent discharge to it without contravening standards established for that stream. The streams in New York State have been classified according to their "best usage".

The receiving stream at the Widmer Project is a tributary to Naples Creek, which is well known in New York State as one of the best fresh water trout streams in the area. Annually, in the spring, lake trout leave Canandaigua Lake and migrate upstream to spawn. Oxygen levels in the stream must be maintained at 4.0 mg/l to support the trout fish life. The tributary to the trout stream is a small intermittent stream with no flow during the critical warm summer months. Consequently, the effluent discharge to the tributary constitutes the entire stream flow during these critical periods. The operating permit conditions established by the New York State Department of Environmental Conservation for the Widmer's Water Pollution Control Plant are as shown in Table 3.

Table 3. Effluent Limitations Water Pollution Control Plant Widmer's Wine Cellars, Inc.

BOD_5 Concentration	60 mg/l
Suspended Solids Concentration	5 mg/l

WATER POLLUTION CONTROL PROJECT

At Widmer's the Water Pollution Control Project included construction of an Interceptor Sewer and a Water Pollution Control Plant. The Interceptor Sewer was constructed parallel to the drainage ditch to intercept all the existing wastewater discharges. The Interceptor Sewer conveys the winery wastewaters to the Water Pollution Control Plant located near the processing plant. All domestic wastes at Widmer's are disposed of utilizing septic tank and leach field facilities.

The Water Pollution Control Plant includes an entrance structure, aeration units, final clarifiers, tertiary sand filter, and an aerobic digester, as shown schematically on Figure 5.

Entrance Structure

The entrance structure includes a parshall flume with a flow meter recorder, a sludge transfer pump, and wastewater conditioning facilities. The parshall flume and flow meter recorder allow the operator to determine the pattern of wastewater flow as well as the total flow into the plant. The sludge transfer pump is a plunger type of pump used to transfer digested sludge from the digester to a tank truck for disposal in the vineyards.

The wastewater conditioning facilities include three chemical feed pumps. pH control is accomplished using a pH probe which monitors the pH of the wastewater leaving the entrance structure. The probe signals a controller which combines it with the flow meter signal and automatically adjusts the feed rate of the caustic soda. Caustic soda is metered into the wastewater flow as required to maintain a pH of the raw wastewater above 7.0. Nutrients required for the biological treatment system are provided by the addition of ammonia water and phosphoric acid. Chemical feed pumps are used to pump these chemicals into the wastewater stream at a rate directly proportional to the influent wastewater flow. A flow signal is received from the recording flow meter and used to control the proportion of the nutrient materials fed by the pump. By manually adjusting the proportioner control, the flow signal can be amplified or reduced to control the nutrient feed rate.

Aeration Units

There are four aeration units which can be operated in parallel or in series at this plant. Aeration units 1 and 2 are 64 feet in diameter with a 10 foot liquid depth, each providing a volume of 120,000 gallons. Aeration units 3 and 4 are 76 feet in diameter and 10 feet deep, each providing a total volume of 192,000 gallons. All aeration units are constructed as earthen lagoons and equipped with two-speed 10 hp mechanical surface aerators. The detention time in the aeration units can be varied from approximately two to eight days (at 0.12 mgd wastewater flow).

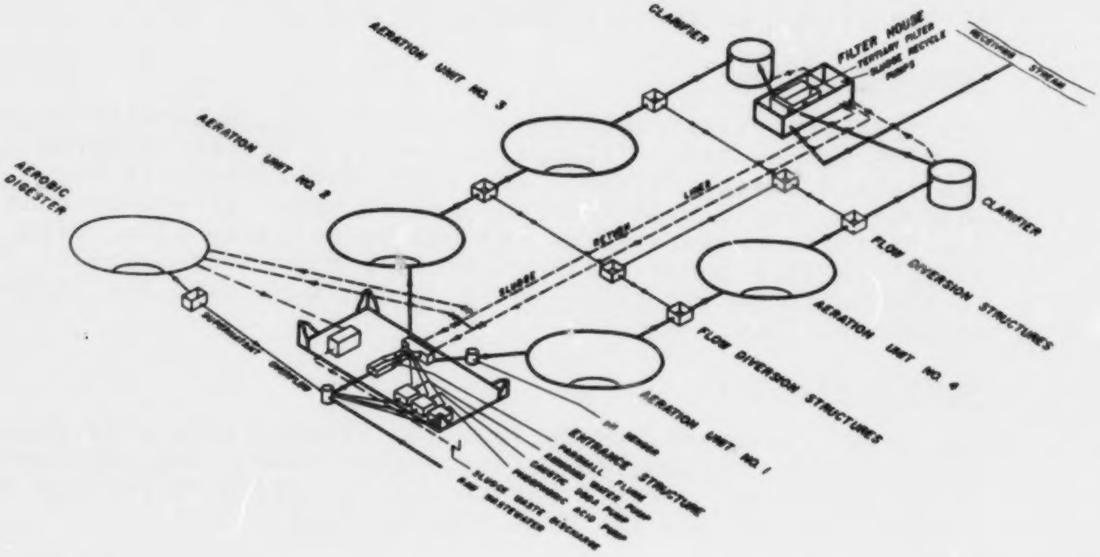
AEROBIC DIGESTER
AERATION UNIT NO. 2
AERATION UNIT NO. 3
CLARIFIER
FILTER HOUSE
TERTIARY FILTER
SLUDGE RECYCLE PUMPS
RECEIVING STREAM
CLARIFIER
FLOW DIVERSION STRUCTURES
AERATION UNIT NO. 4
LINES
FILTER
SLUDGE
FLOW DIVERSION STRUCTURES
AERATION UNIT NO. 1
SUPERNATANT OVERFLOW
pH SENSOR
ENTRANCE STRUCTURE
PARSHALL FLUME
AMMONIA WATER PUMP
CAUSTIC SODA PUMP
PHOSPHORIC ACID PUMP
SLUDGE WASTE DISCHARGE
RAW WASTEWATER

Figure 5

WASTEWATER PROCESS FLOW SCHEMATIC
WATER POLLUTION CONTROL PLANT
Widmer's Wine Cellars, Inc.

Clarifiers

Clarification is accomplished using two 16 foot diameter units with a 7 foot liquid depth. These units provide 2.81 hours detention of the design average flow during pressing season (0.12 mgd). Each clarifier is equipped with rapid sludge removal equipment in an effort to minimize the detention time of the sludge in the clarifier.

Tertiary Filter

The tertiary filter includes two sand beds, each with an area of 67.5 square feet. Figure 6 shows a schematic diagram of the tertiary sand filter. The sand filter beds are very similar to rapid sand filters used in water treatment plants. The filters are located in the Filter Building along with sludge recycle pumps that are used to return the settled sludge to the entrance structure where it combines with the influent wastewater flow.

Aerobic Digester

The aerobic digester is 60 foot in diameter with a 10 foot liquid depth constructed as an earthen pond. One two-speed 10 hp mechanical surface aerator is installed to provide the required oxygen for the digestion process.

Laboratory

New Laboratory equipment has been purchased and a laboratory constructed adjacent to the existing wine laboratory.

CONSTRUCTION COST

The cost for construction of the Water Pollution Control Facilities is shown in Table 4.

Table 4. Construction Cost Water Pollution Control Facilities Widmer's Wine Cellars, Inc.

Interceptor Sewer	$ 33,400.00
Plant Equipment	94,247.00
General Plant Construction	280,139.66
Electrical Construction	38,113.22
Total Construction Cost	$ 445,899.88

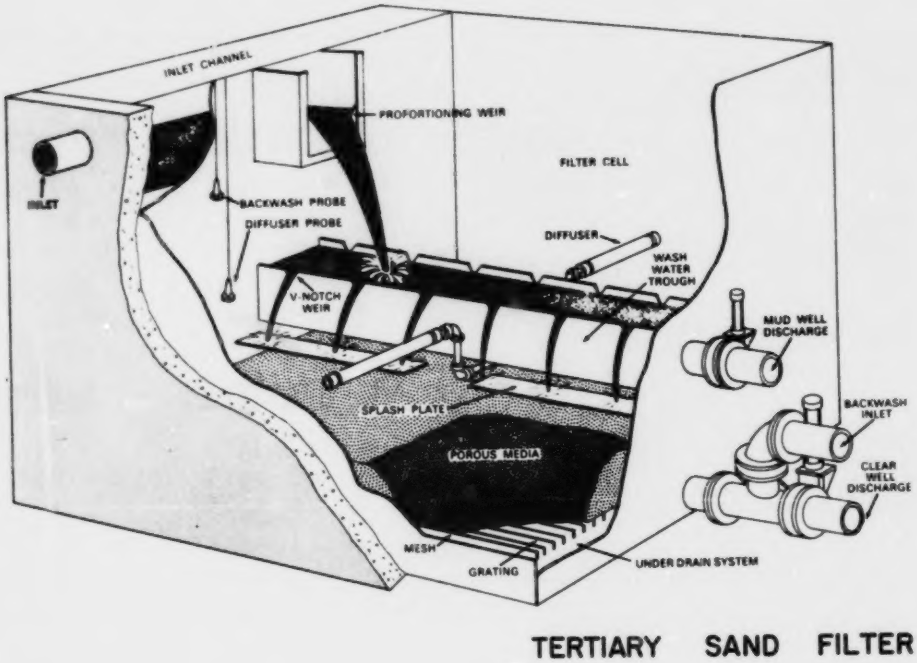
INLET CHANNEL
INLET
PROFORTIONING WEIR
FILTER CELL
BACKWASH PROBE
DIFFUSER PROBE
DIFFUSER
WASH WATER TROUGH
V-NOTCH WEIR
MUD WELL DISCHARGE
SPLASH PLATE
BACKWASH INLET
POROUS MEDIA
CLEAR WELL DISCHARGE
MESH
GRATING
UNDER DRAIN SYSTEM
TERTIARY SAND FILTER

Figure 6

TERTIARY SAND FILTER
Widmer's Wine Cellars, Inc.

PLANT PERFORMANCE

After placing the Plant in operation and stabilizing the biological process, the data developed indicated performance generally as anticipated. Table 5 shows 90th percentile data on plant performance.

Table 5. Plant Performance Water Pollution Control Plant
Widmer's Wine Cellars, Inc.

PRESSING SEASON

	Influent	Effluent	Removal
COD	1320 mg/l	100 mg/l	92.5%
BOD_5	1010 mg/l	40 mg/l	96 %
Suspended Solids	-----	25 mg/l	-----

PROCESSING SEASON

	Influent	Effluent	Removal
COD	1730 mg/l	60 mg/l	96%
BOD_5	1370 mg/l	33 mg/l	98%
Suspended Solids	------	28 mg/l	---

Treatment of Cheese Processing Wastewaters in Aerated Lagoons

William C. Boyle and Lawrence B. Polkowski
Polkowski, Boyle, and Associates
Madison, Wisconsin

INTRODUCTION

The evaluations and findings reported herein were supported by EPA Project No. 12060 EKQ for post-construction studies over a 12-month period to demonstrate and evaluate the use of aerated lagoons for the treatment of cheese wastes. The authors of this report were not engaged to design or size the system employed, select equipment utilized nor were they consulted regarding the process flowsheet applicable to this wastewater treatment scheme. The authors were retained to conduct the post construction study, direct frequency of sampling, recommend analyses to be performed, and evaluate and present findings of the performance of the aerated lagoon systems for the wastes received at the treatment site.

The principal objectives of this study were to demonstrate the performance of a staged aerated lagoon treatment plant utilizing the Helixor* type of submerged aeration system treating cheese processing wastes over a 12 month period of operation. Part of the evaluation was directed to the performance of the aeration equipment employed wherein mixing effectiveness in terms of liquid velocities produced, uniformity of dissolved oxygen levels and sludge accumulations could be ascertained under the conditions of operation and geometric configuration of the lagoons employed. In addition the oxygen transfer efficiency of the aeration system employed was evaluated under field conditions. A major part of this study was to determine the BOD removal rate functions for each stage of aerated lagoon treatment noting the influence of BOD loadings, temperature and seasonal variations in loading and performance obtained for this type of biological treatment. The theoretical and applied concepts of biological treatment related to low-solids aerated lagoon systems were employed to evaluate the treatment system. Lastly, the performance of this type of treatment was evaluated in terms of costs associated with the wastewater characterists and the pounds of cheese produced.

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*subsurface aeration unit manufactured by Polcon Corporation, Montreal, Canada

EXPERIMENTAL SYSTEM

The wastewater treatment system consists of two equal volume aerated lagoons with a staged flowsheet wherein the effluent from Lagoon No.1 is passed to Lagoon No. 2 before final discharge of the treated effluent. The lagoons have earth embankments with side slopes of 3 horizontal to 1 vertical, a water depth of 12 feet at the lowest central portion of the lagoon, and a length-width measurement of 155 feet by 123 feet at the water line for a volume of 955,000 gallons each (Figure 1). The first lagoon is provided with thirteen 6 foot long 18 inch diameter Helixors arranged in a pattern of 2 rows of 4 units equally spaced along the intersection of the flat bottom and side slopes of the long dimension of the lagoon. Five additional units were added to this lagoon between the 2 rows of four units such that 4 of the five units were equally spaced in 2 rows between the 1st and 2nd and 2nd and 3rd aeration units. The fifth additional aerator was equally spaced between the third and fourth unit of the initial eight unit arrangement (Figure 1). The second lagoon is provided with three aeration units arranged in a triangular pattern close to the inlet end of the lagoon in the lowest central section of the lagoon. A separate blower building with two 240 cfm Gardner Denver rotary blowers (one standby), Model 3CDL5, provided the air supply to both lagoons. Usual operating conditions required only one compressor to be operative and it was assumed that the air flow was distributed between the two aerated ponds with 80% of the air flow supplied to Lagoon No. 1 and the remainder to Lagoon No. 2. The air flow regulation and distribution was effected by the number and size of air orifices providing air directly to each Helixor. The air header piping and valving was arranged to permit the control of air to a pair of aeration units in most instances; however, several aeration headers supplied air to a single unit. The valving in the aeration headers were used only for fully open or closed conditions wherein the inlet orifices controlled the distribution of air flow.

The wastewater is conveyed to the treatment lagoons through about 3000 ft of 8 inch transite pipe, passes through a 4 inch inverted siphon to a Snyder-Teague sampling station and thence is discharged through a 4" cast iron pipe to a point of entry to Lagoon No. 1 at approximately mid-depth. The effluent from Lagoon No. 1 passes through a submerged 4 inch cast iron pipe to the secondary lagoon. The water surface elevation in both lagoons is controlled by the placement of 4 inch cast iron riser pipe with the inlet to this pipe, or overflow from the lagoons, at a fixed elevation to maintain the 12 foot water depth. The effluent from the secondary lagoon passes through another Snyder-Teague sampling station.

KENT CHEESE WASTEWATER LAGOONS

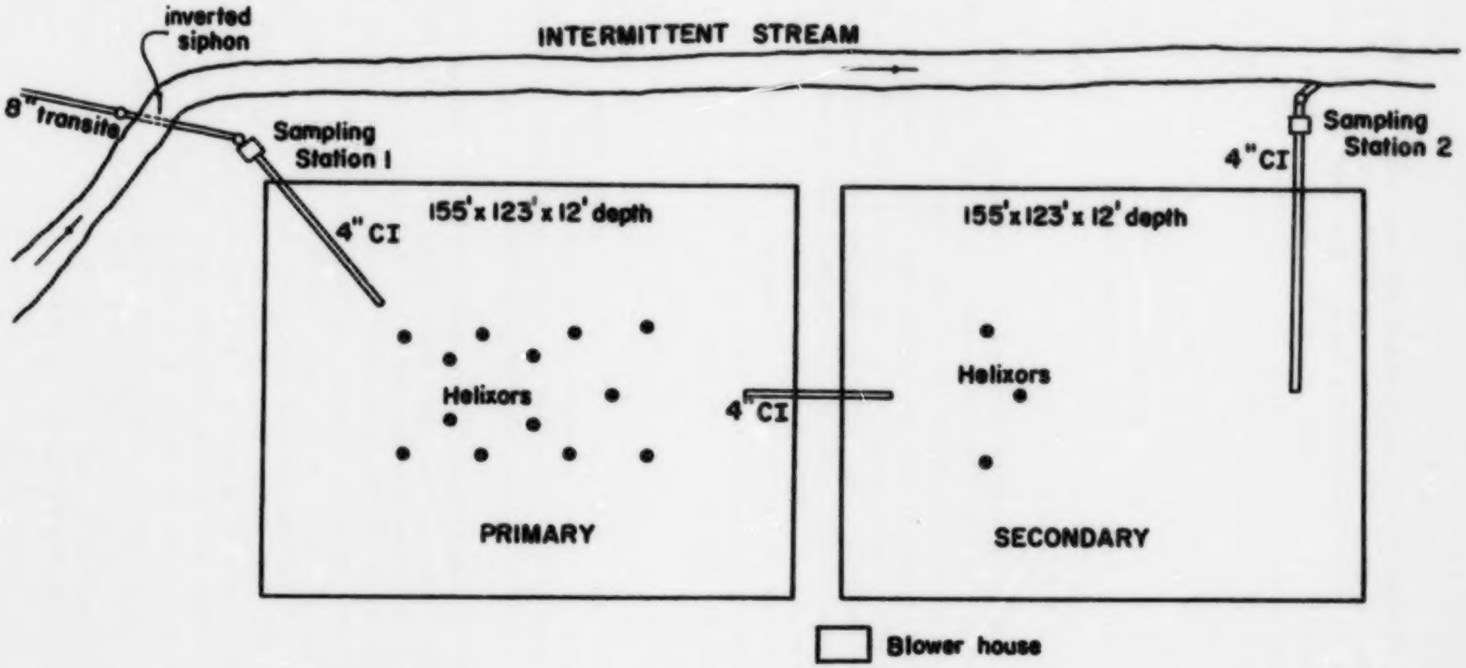

inverted siphon
INTERMITTENT STREAM
8" transite
Sampling Station 1
4" CI
155' x 123' x 12' depth
Helixors
PRIMARY
4" CI
155' x 123' x 12' depth
Helixors
SECONDARY
4" CI
Sampling Station 2
Blower house

FIGURE 1

OPERATION

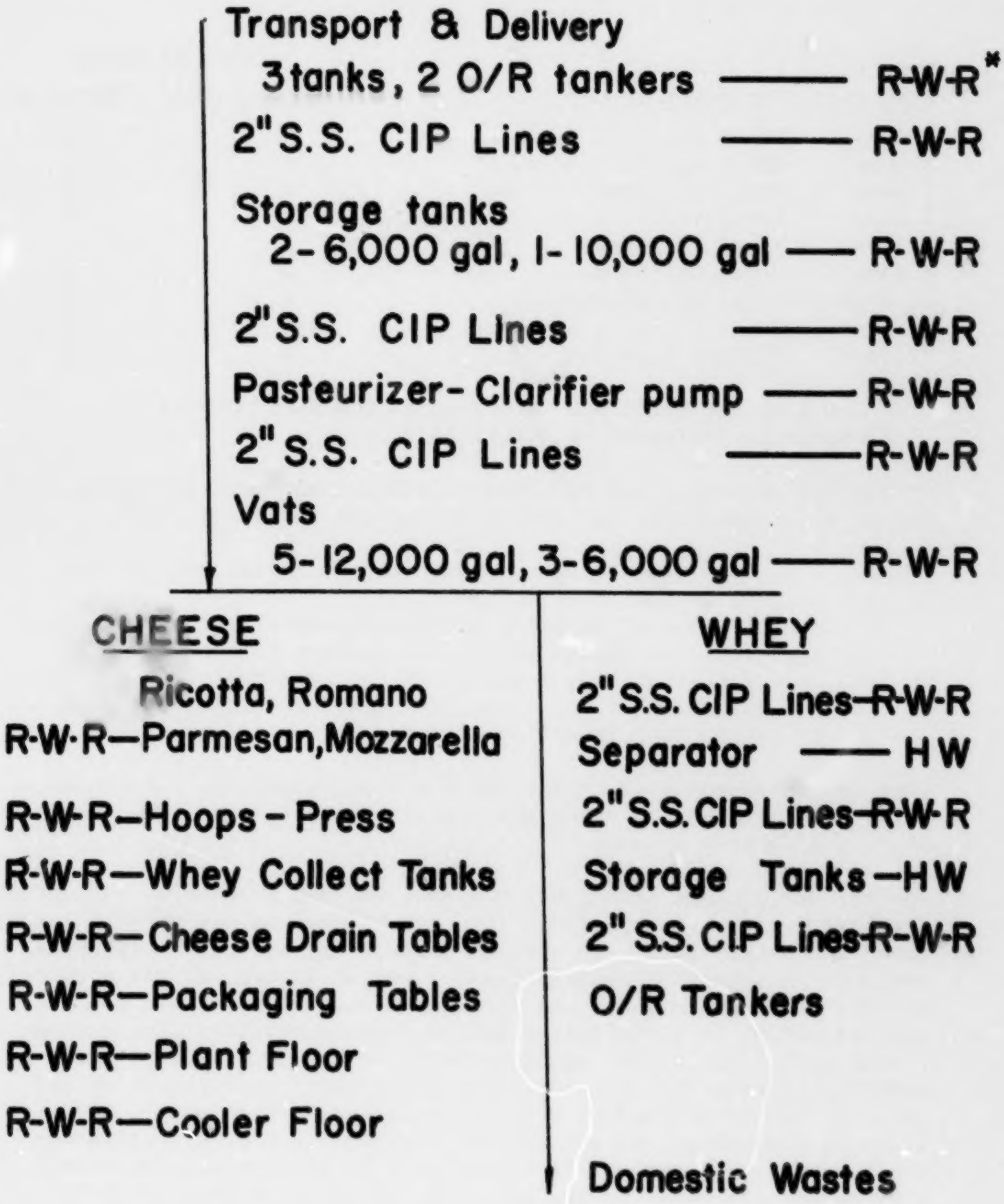
The treatment system handled the wastewater from a cheese making industry specializing principally in products of Ricotta, Parmesan, Romano, and Mozzarella cheese. The sources of wastewater were primarily from rinses and washes associated with the storage of milk, transmission lines, vats and pasteurizer with a limited amount of wastes of domestic origin. The by-product whey was collected and transported to another site for recovery and only whey wastes associated with washing and rinsing were discharged to this treatment system. The sources of wastewater treated by the aerated lagoon system are shown in Figure 2. The quantity or quality of rinsewater from each operation was not determined in this study, but rather the collective properties of the total discharge to the lagoon system were determined.

The sampling stations provided flow measurements and flow composited samples for the raw waste water and treated effluents. Serious operating difficulties resulted in the raw waste sampling station due to the accumulation of cheese solids upstream from the flow measuring control section. The accumulation of solids resulted in inaccurate flow measurements. The control section was modified somewhat but proved to present difficulties throughout the period of the study. In order to obtain reliable measurements of flow, it was necessary to meter water use at the cheese processing plant and to determine boiler feedwater requirements and the extent of infiltration of the conveying sewerage system for reliable flow information. All reported data requiring flow input were corrected for the inaccuracy of this sampling station. A sampling station was not provided between the primary and secondary lagoons; thus, grab samples of the primary lagoon contents were taken near the effluent discharge pipe. Because of the long detention times experienced in each lagoon, 45-75 days, and the ability to maintain a dispersed or mixed condition throughout the primary lagoon, this procedure was deemed acceptable.

Certain measurements were made daily for operation of the treatment works such as D.O., pH, alkalinity, settleable solids, temperature, and flow quantity whereas more detailed analyses for evaluating the performance of the treatment system were obtained for raw wastewater influent, primary lagoon contents near effluent structure, and secondary lagoon effluent on an eight day sampling frequency. This permitted each day of the weekly operation to be sampled every 56 days throughout the one year study commencing on January 14, 1971. A sampling schedule is outlined in Table I. All the analyses indicated in Table I were performed by Corning Laboratories, Inc., Cedar Falls, Iowa. The lagoon system had been in operation approximately eight months prior to initiating the sampling program; thus, the data presented does not represent start-up conditions, but there are indications that the performance did not reach steady state in all respects particularly regarding seasonal variations.

FIGURE 2

SOURCES OF CHEESE PLANT WASTE


Transport & Delivery
3tanks, 2 O/R tankers — R-W-R*
2" S.S. CIP Lines — R-W-R
Storage tanks
2-6,000 gal, 1-10,000 gal — R-W-R
2" S.S. CIP Lines — R-W-R
Pasteurizer-Clarifier pump — R-W-R
2" S.S. CIP Lines — R-W-R
Vats
5-12,000 gal, 3-6,000 gal — R-W-R
CHEESE
Ricotta, Romano
R-W-R—Parmesan, Mozzarella
R-W-R—Hoops-Press
R-W-R—Whey Collect Tanks
R-W-R—Cheese Drain Tables
R-W-R—Packaging Tables
R-W-R—Plant Floor
R-W-R—Cooler Floor
WHEY
2" S.S. CIP Lines—R-W-R
Separator — HW
2" S.S. CIP Lines—R-W-R
Storage Tanks—HW
2" S.S. CIP Lines—R-W-R
O/R Tankers
Domestic Wastes

* R-W-R - Rinse, wash, rinse
HW - Hand wash

TABLE I

SAMPLING SCHEDULE

Sampling Frequency	Parameter or Determination	Sampling Points Raw	Primary	Secondary
8 days	BOD 5 day 20°C Total	x	x	x
8 days	BOD 5 day 20°C Soluble*	x	x	x
8 days	Total Suspended Solids	x	x	x
8 days	Total Volatile Suspended Solids	x	x	x
8 days	Total Coliforms	x		x
8 days	Fecal Coliforms	x		x
30 days	Total Phosphorus	x		x
30 days	Total Kjeldahl Nitrogen	x		x
30 days	Nitrate Nitrogen	x		x

All Analyses performed according to Standard Methods
*Analysis performed on sample filtrates

Additional operating and performance evaluations were performed during the experimental period including the following items,

1. D.O. measurements with respect to horizontal and vertical control in the primary lagoon,
2. measurements of velocity in the horizontal plane at various locations and depths within the primary lagoon,
3. measurement of oxygen uptake of the treatment lagoon contents,
4. determination of the oxygen transfer coefficients of α and β to enable the evaluation of the aeration system employed.

Various other operating conditions and observations were recorded on a routine basis to assist in the overall evaluation of the performance of this treatment system.

Special measurement techniques employed for the purpose of evaluating the aeration system employed a grid established in the primary lagoon above the water surface to provide a measuring base for horizontal control. At the time oxygen transfer was evaluated, it was necessary to have a measureable D.O. in the lagoon and evidence that the D.O. was maintained at a uniform or steady state condition. The oxygen uptake or demand of the lagoon contents were determined by taking a number of representative samples of the mixture under aeration and placing them in bottles capable of excluding further oxygen transfer from the atmosphere and wherein the decrease in D.O. concentration was measured with respect to time with a Yellow Springs Instrument D.O. probe. In order to evaluate the influence of photosynthetic plankton on the oxygen transfer in the lagoon, oxygen uptake measurements were made both on rates observed under light and dark conditions. There was no discernible difference in the rates observed which indicated that oxygen transfer or supply from this source was negligible during the test periods. The efficiency was determined on the basis of line to water for the complete aeration system wherein power input was metered in each instance for amperage and voltage drawn. The results were presented in terms of pounds oxygen transferred per kw-hr. Thus, the reported efficiency included oxygen transferred from the atmosphere as well as oxygen transferred by virtue of the aeration system employed.

The measurements were corrected to standard conditions of zero dissolved oxygen and 20°C with corrections for α and β. A representative sample of the lagoon contents were tested in Madison laboratories in a diffused air system to compare transfer rates for the waste mixture and tap water for two replicate samples. The α values were corrected for the oxygen uptake rates in the mixture at this time. The value α was obtained as an average of the ratio of the transfer rates in the wastewater and tap. The value β was determined on the basis of the highest D.O. obtained in waste for a given temperature, checked by the Winkler D.O. method, against the D.O. at saturation for tap water at the same temperature.

The velocity profiles in the aerated lagoon were made with the use of a Gurley Current Meter which was fixed in the horizontal plane by attachment to a vertical rod. The current meter was rotated in the horizontal plane at a predetermined depth and the maximum velocity and direction were noted to obtain a vectoral representation of the water movement in the lagoon. The velocity was observed in four directions parallel to the sides of the lagoon in the central portion of the aerated lagoon where a single maximum velocity component was not observed due to the highly undirected flow patterns evident within the area bounded by the aeration devices. An attempt was made to measure the vertical velocity component immediately above the discharge of the aeration device but the variation in fluid density as a result of high levels of air entrainment caused on the measurements to be somewhat erratic. Measurements were made one foot below the surface, mid-depth and one foot from the bottom.

RESULTS AND DISCUSSION

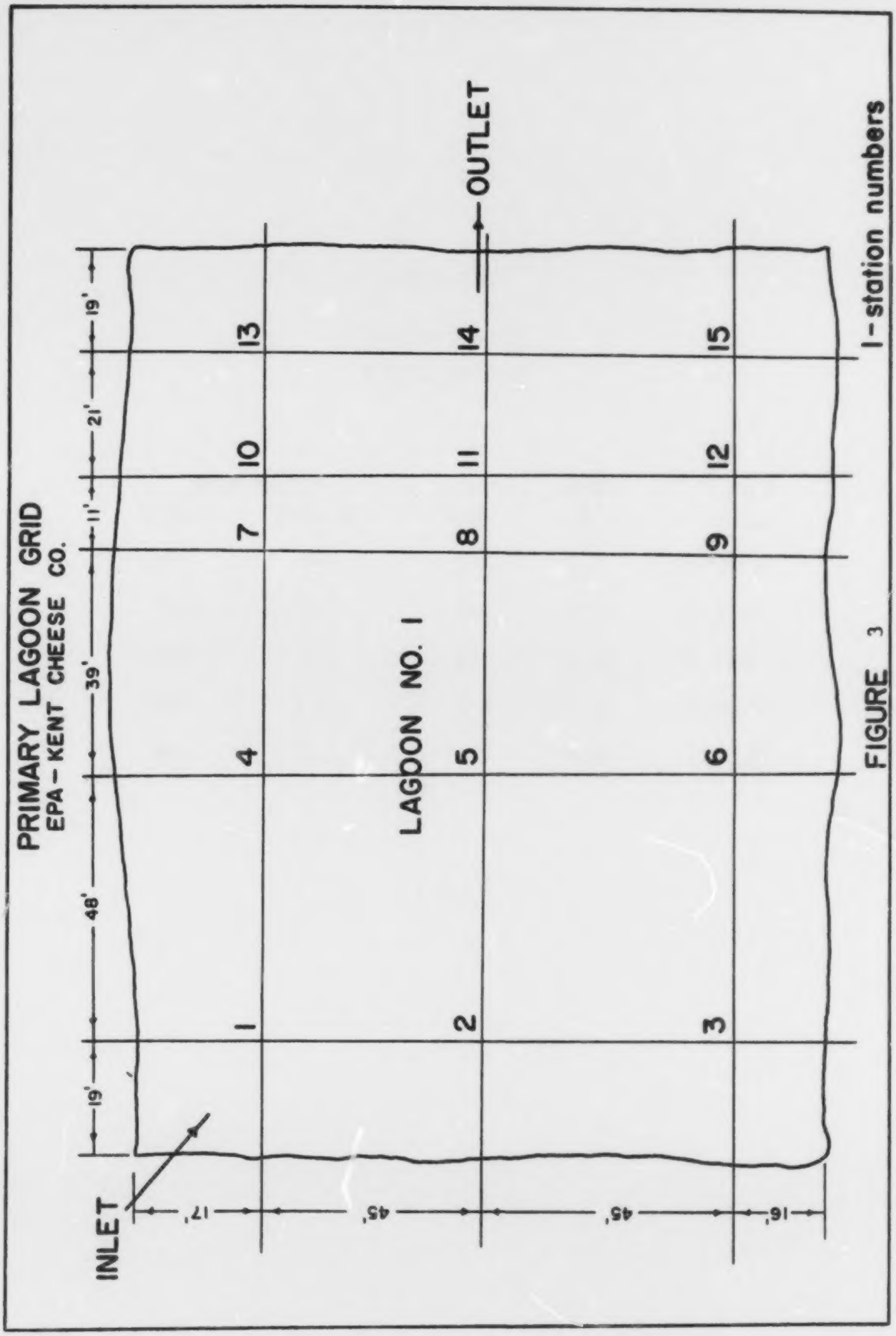
Aerator Performance

The performance of the Polcon Corporation subsurface aerators (Helixors) was evaluated over the one year period in the primary lagoon only. As indicated earlier, the lagoon was sampled at a number of points on a grid (Figure 3) at selected depths to determine the oxygen uptake rates, dissolved oxygen concentration, and temperature. Tests were repeated five times over the grant period in order to evaluate performance under different waste loading and environmental conditions.

Oxygen Uptake Rates - The average oxygen uptake rates recorded in the primary lagoon over the one year study period are presented in Table II. The values reported represent the average uptake measured at a number of selected points within the lagoon. Normally, the uptake rates measured on any given day were within 10 percent of each other. The uptake rates reported were not converted to specific uptake rates (mg O_2/gVSS/day) since the volatile solids fraction measured in this lagoon was not well correlated with the active biomass during the study period. Large amounts of suspended volatile matter associated with the wastewater contributed significantly to the total volatile fraction measured. The influence of algal cells on the oxygen uptake rates in the primary lagoon were negligible as measured by both dark and light bottle uptake rates.

Examination of the uptake rates presented in Table II suggest that the primary lagoon was relatively active as compared with other aerated lagoon systems. The analysis obtained in May, 1971, occurred during the anaerobic period and indicates that the lagoon was extremely active. As discussed later, this high rate of oxygen consumption was believed to be due to the rapid solubilization of organic matter and synthesized cells which had settled in the lagoon and had subsequently been stored over the cold winter months.

Oxygen Transfer Capacity - The values of the oxygen transfer capacity of the lagoon contents, as measured by the ratio of the oxygen transfer coefficients in the waste to that in tap water, are reported in Table III as Alpha. These values represent the average values obtained from several points within the lagoon. Alpha appeared to fluctuate seasonally being highest during the summer months. There was not sufficient data to establish any reliable correlations between alpha and lagoon BOD solids or temperature, but it is reasonable to assume that changes in the metabolic activity within the lagoon would result in changes in the oxygen transfer relationships.



PRIMARY LAGOON GRID
EPA-KENT CHEESE CO.
LAGOON NO. 1
INLET
OUTLET
1-station numbers

FIGURE 3

TABLE II

OXYGEN UPTAKE
PRIMARY LAGOON

DATE	TEMP. °C	D.O. mg/1	UPTAKE RATE mg/1/hr	UPTAKE RATE lb/day
11-20-70	6.3	2.9	2.1	427
5-23-71	17.0	0.0	5.6	1165
7-21-71	24.0	4.5	1.2	250
8-21-71	23.5	4.7	0.8	167
10-7-71	16.5	2.2	1.2	250

TABLE III

OXYGEN TRANSFER DATA
PRIMARY LAGOON

DATE	TEMP.	D.O.	α	β	STD. TRANSFER[1]	
	°C	mg/l			lb/kw-hr.	lb/hp-hr.
11-19-70	6.3	2.9	0.75	0.96	5.55	4.14
5-23-71	17.0	0.0	0.88	0.96	----	----
7-21-71	24.0	4.5	0.90	0.98	3.55	2.65
8-21-71	23.5	4.7	0.94	0.98	1.14	0.85
10-7-71	16.5	2.2	0.70	0.98	3.00	2.25
Average (excluding 8-21-71)			0.81	0.97	4.03	3.01

1 - 20°C, D.O. = 0.0, Tap water

The solubility of oxygen was only slightly affected by the wastewater characteristics within the primary lagoon. Normally values of beta in long detention-type processes such as the one studied here approach 1.0.

Aeration Efficiency - The aeration efficiency of the Polcon Corporation Helixors are presented in Table III for the five test days. The aeration efficiencies were computed by employing the measured oxygen uptake rates, dissolved oxygen concentration, alpha, beta, and temperature. The value of the aeration efficiency was corrected to standard conditions of 20°C, tap water (alpha and beta equal 1.0), and a dissolved oxygen concentration of 0.0 mg/l. A sample calculation appears in the Appendix.

The overall aeration of efficiencies in the primary lagoon were estimated by assuming that approximately 80% of the air provided by the blower was directed to the primary lagoon, since 13 of the 16 helixors were located in the primary lagoon. During the August 21, 1971, test, both blowers were in operation resulting in a doubling of the power input to the aerators. Yet the actual measureable oxygen transfer rate was not appreciably higher than for other test periods. It has been well documented in the literature that aeration efficiency decreases with increased air flow rates and this analysis tends to verify that fact. In addition, however, it was determined that, during the operation of both compressors, the line pressures increased very significantly requiring the bleeding of air from one of the headers. This was practiced by the use of a "blow-off" or "by-pass" Helixor in the secondary lagoon. Thus, the poor transfer rates for August were not included in the overall average for aeration efficiency.

The measured transfer efficiencies of the Helixor units were within the values normally expected for this type of unit but tended to be on the low side of expected performance. Whether this was due to undersizing of the air headers, the geometry of the Helixor-basin configuration, or was, in fact, the actual field expectation for these units has not been determined but it suggests that caution must be exercised in sizing aerators for lagoon systems.

Oxygen Dispersion - An important function of aeration devices in biological processes is the dispersion of oxygen throughout the basin contents. Normally, rule of thumb criteria recommend that at least

4 to 10 horsepower per million gallons (hp/MG) be supplied to insure adequate oxygen dispersion. For the primary lagoon, 8.5 hp/MG were provided during the single blower operation. The results of dissolved oxygen analyses in the primary lagoon for the five field surveys are presented in Table IV. Examination of this data indicates that oxygen was well dispersed throughout the primary lagoon.

Mixing and Solids Suspension - The D.O. parameter would be indicative of the dispersion which can be affected of substances in the dissolved state such as soluble B.O.D. However, the distribution of particulate matter such as biological floc would be a function of the velocity distribution and the velocities necessary to keep the particulate matter in suspension. Normally, in aeration tanks in wastewater treatment, velocities along the bottoms of these units would range from 1.0 to 2.0 fps depending upon the geometry of the aeration system employed. Velocity measurements within the lagoon can serve only to show flow regimes developed within the lagoon with the given aeration equipment for the placement arrangements employed and the geometry of the lagoon. Effectiveness of the system in terms of keeping particulate solids in suspension can be evaluated in a qualitative way by determining the location and extent of solids deposition on bottom surfaces of the lagoon.

The maximum velocities observed in primary lagoon at the various depths are reported in Table V for one blower, 192 cfm, and two blowers, 384 cfm. These airflow rates correspond to 2.3 cfm per lineal foot and 4.6 cfm per lineal foot respectively along the longest bottom dimension of the lagoon.

Because of the upward vertical velocity components in the immediate vicinity of the inlet and outlet of the Helixors and the necessary compensating downward movement of water between adjacent aeration units, no definitive flow pattern is discernible. However, in zones peripheral to the aeration section, where the bottom of the lagoon is sloped to intersect the water surface, horizontal velocities were measured near the water surface indicating a general circulation pattern towards the periphery of the aerated lagoon with velocities ranging from less than 0.1 to 0.8 fps. Likewise, to compensate for the outward movement of water toward the periphery of the lagoon near the surface, water movement must be in the opposite direction near the bottom of the lagoon, the measurements and magnitude of which was less discernible. Thus, a circulatory pattern of flow developed, in the outer prism shaped sections similar to that which is depicted in Figure 4.

TABLE IV
DISSOLVED OXYGEN CONCENTRATION
PRIMARY LAGOON

	Station Number														
Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
11/19/70	2.7*	2.9	2.9	2.7	3.1	2.9	3.0	2.8	2.8	2.8	2.8	2.7	2.8	2.7	2.6
	2.7	2.8	2.9	2.7	3.0	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.5
	-	2.8	2.7	2.7	3.0	2.9	2.9	2.8	2.7	2.8	2.7	2.7	2.6	2.7	-
5/14/71	0.1	0.1	0	0	0.3	0.1	0	0.3	0.1	0.1	0.3	0	0	0.1	0.1
	0.1	0.1	0	0	0.2	0.1	0	0.2	0.1	0.1	0.3	0	0	0.1	0
	-	0.1	0	0	0.2	0	0	0.1	0	-	0.3	0	0	0.1	0
7/21/71	4.4	4.4	4.4	4.3	4.3	4.4	4.6	4.7	4.2	4.8	4.4	4.3	4.9	4.7	4.4
	4.3	4.2	4.3	4.3	4.3	4.3	4.7	4.7	4.2	4.7	4.4	4.2	4.8	4.7	4.4
	-	4.2	-	3.0	4.3	4.2	4.7	4.5	4.2	4.7	4.3	-	-	-	-
8/26/71	4.1	4.3	4.7	4.3	4.4	4.7	-	4.7	-	-	4.4	-	4.4	4.5	4.5
	3.9	4.6	-	4.3	4.4	4.7	-	4.6	-	-	4.4	-	4.4	4.5	-
	-	3.0	-	4.4	4.5	4.7	-	4.6	-	-	4.5	-	-	4.5	-
10/7/71	2.2	2.2	2.7	2.3	2.3	2.4	2.3	2.4	2.3	2.3	2.1	2.3	2.4	3.0	-
	2.0	2.1	2.7	2.4	2.3	2.4	2.3	2.2	2.3	2.3	2.1	2.3	2.3	2.6	-
	2.1	2.0	-	2.3	2.3	2.4	2.3	2.2	2.3	2.3	2.1	2.3	2.3	2.5	-

*D.O. values in mg/l at 1 ft, 3 ft, and 5 ft.

TABLE V

VELOCITY DISTRIBUTIONS IN PRIMARY LAGOON

November 7, 1971

Station	One Compressor			Two Compressors		
	Surface	Mid Depth	Bottom	Surface	Mid Depth	Surface
1	0.1	0.0	0.0	0.0-0.2	0.0-0.2	0.0
2	0.1-0.2	0.0	0.0	0.1-0.2	0.0-0.1	0.1-0.2
3	0.0-0.1	0.0-0.1	0.0	0.2-0.3	0.2-0.3	0.0-0.1
4	0.4	0.1	0.0	0.6-0.8	0.3-0.4	0.1-0.2
5	0.2-0.5	0.2-0.3	0.1	0.2-0.6	0.2-0.3	0.0-0.2
6	0.1	0.0	0.0	0.0-0.2	0.0-0.2	0.0-0.1
7	0.2	0.0	0.0	0.4-0.5	0.0-0.2	0.0-0.1
8	0.5-0.8	0.2	0.2	0.8	0.2	0.2
9	0.1	0.0	0.1	0.2	0.1	0.1
10	0.0	0.2	0.0	0.4-0.5	0.0-0.1	0.0
11	0.3	0.2	0.1	0.3	0.2	0.1-0.2
12	0.1	0.0	0.1	0.1	0.1	0.0
13	0.2	0.0	0.0	0.2	0.0	0.0
14	0.2	0.1	0.0	0.2	0.0	0.1
15	0.0	0.0	0.0	0.1	0.0	0.0

All values of velocity in ft/sec.

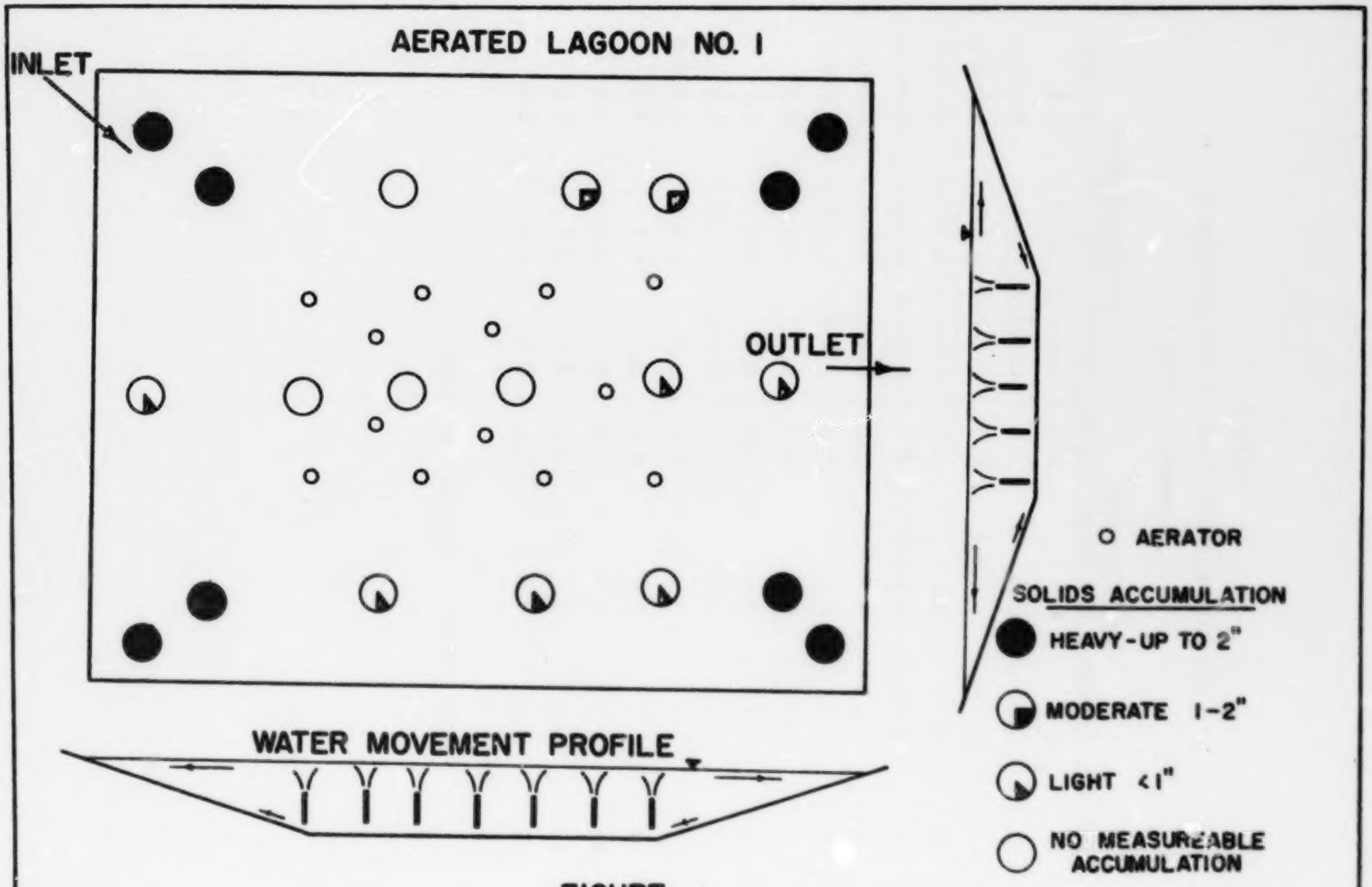

AERATED LAGOON NO. 1
INLET
OUTLET
WATER MOVEMENT PROFILE
○ AERATOR
SOLIDS ACCUMULATION
HEAVY-UP TO 2"
MODERATE 1-2"
LIGHT <1"
NO MEASUREABLE ACCUMULATION

FIGURE 4

Perhaps a more meaningful observation that was made to ascertain the ability of the aeration system to keep solids in suspension was to estimate the accumulation of solids on the lagoon bottom. Utilizing a D.O. probe, an estimate of the sludge accumulation was made by lowering the probe to an elevation where the D.O. decreased to zero and noted, and to a point where the weighted unit would come to rest, a point which was presumed to be at the bottom of the lagoon. The results were plotted qualitatively by the graphical representations for deposit as shown in Figure 7. It is noted that the greatest accumulation reported on the date of test occurred in the non-aerated zones of the lagoon corresponding to the tapered prism sections representing sloped sections of the lagoon nearest the intersection of the two adjacent sloped bottom sections. The least discernible deposits of solids occurred in the central aeration zone which may be due either to the higher levels of fluid turbulence to keep the solids in suspension or due to the greater diffusion of oxygen in the lighter accumulations of sludge at these points. For longer periods of treatment plant operation, it is likely that greater accumulations will occur. However, at the time the determinations were made, it appeared that the accumulation of solids would not present a serious problem for this system.

Lagoon Performance

The performance of the staged lagoon system was interpreted in terms of several measured parameters: BOD_5 (total and soluble), suspended solids, nitrogen, phosphorus, coliforms (total and fectl). The results reported herein are subdivided in accordance with these parameters. The loading to the lagoon system is summarized for the one year study in Figure 8. It is apparent from this figure that flow and organic load to the lagoon is quite variable over the one year period. Hourly flows over a 24 hour period are presented in Figure 9 for two days, January 24 and 25, 1972. Analysis of this data indicates that the ratio of maximum to average flow for the day was 1.9. The average flow rate over the 12 month study was 17,000 gallons per day including Sundays.

The apparent cyclic variation in BOD and solids loading to the lagoons (Figure 8) are due to the sampling schedule employed. Therefore, a trend line was difficult to describe. Average BOD loading over the 12 month study was 270 lb/day and suspended solids loading was 85 lb/day. An average of 13,000 lb cheese were produced per day (excluding Sunday) requiring approximately 1.5 gallons of water per lb of cheese and resulting in 24 lbs of BOD and 7.6 lb of suspended solids per 1000 lb of cheese produced.

Biochemical Oxygen Demand - The performance of the lagoon system in removing biodegradable organic matter was measured by the five day

CHEESE PROCESS WASTEWATER LAGOONS
EPA - KENT CHEESE CO.
JAN 1971 - 1972

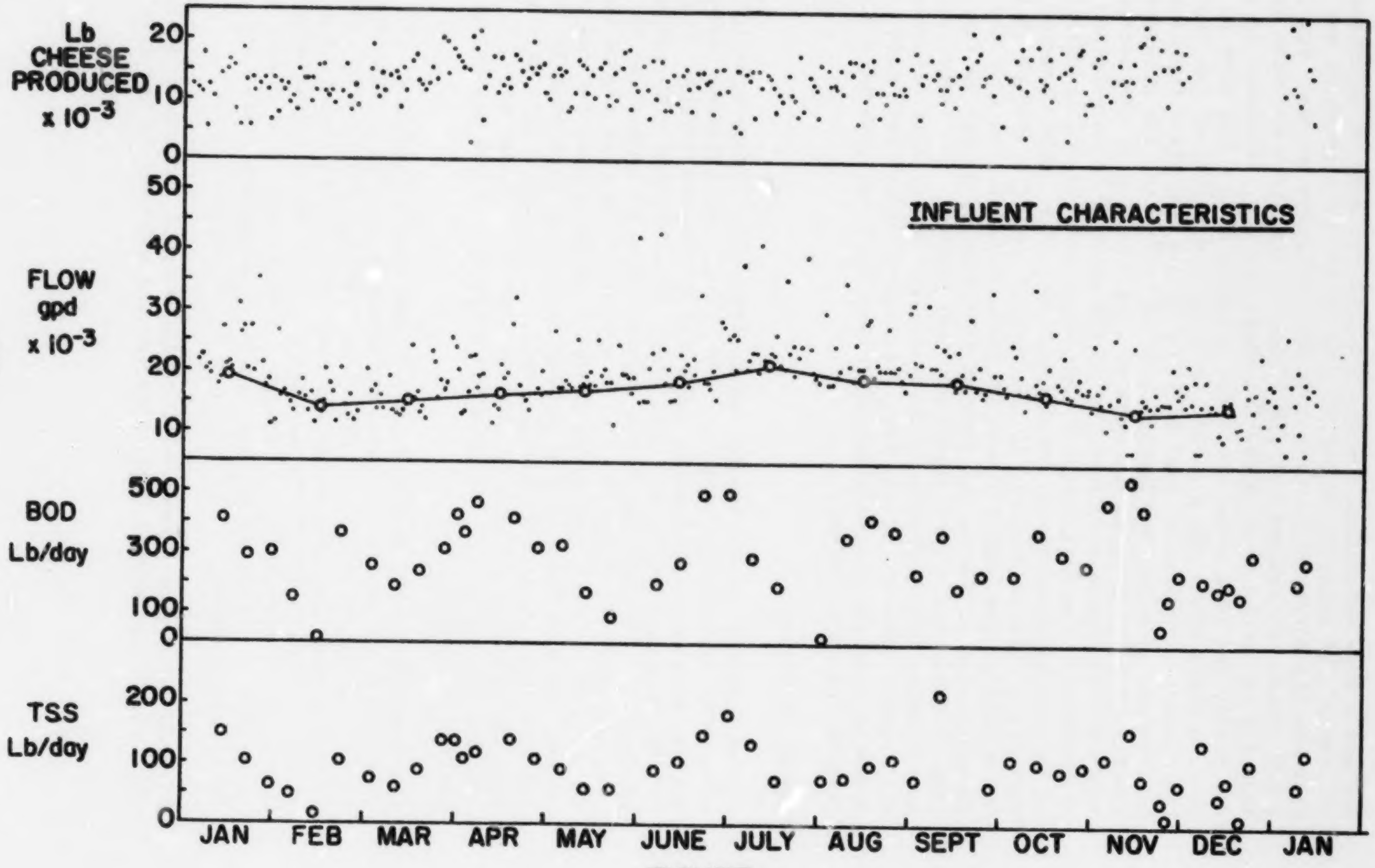


FIGURE 5

CHEESE PROCESS WASTEWATER FLOWS

EPA - KENT CHEESE CO.
JAN 1972

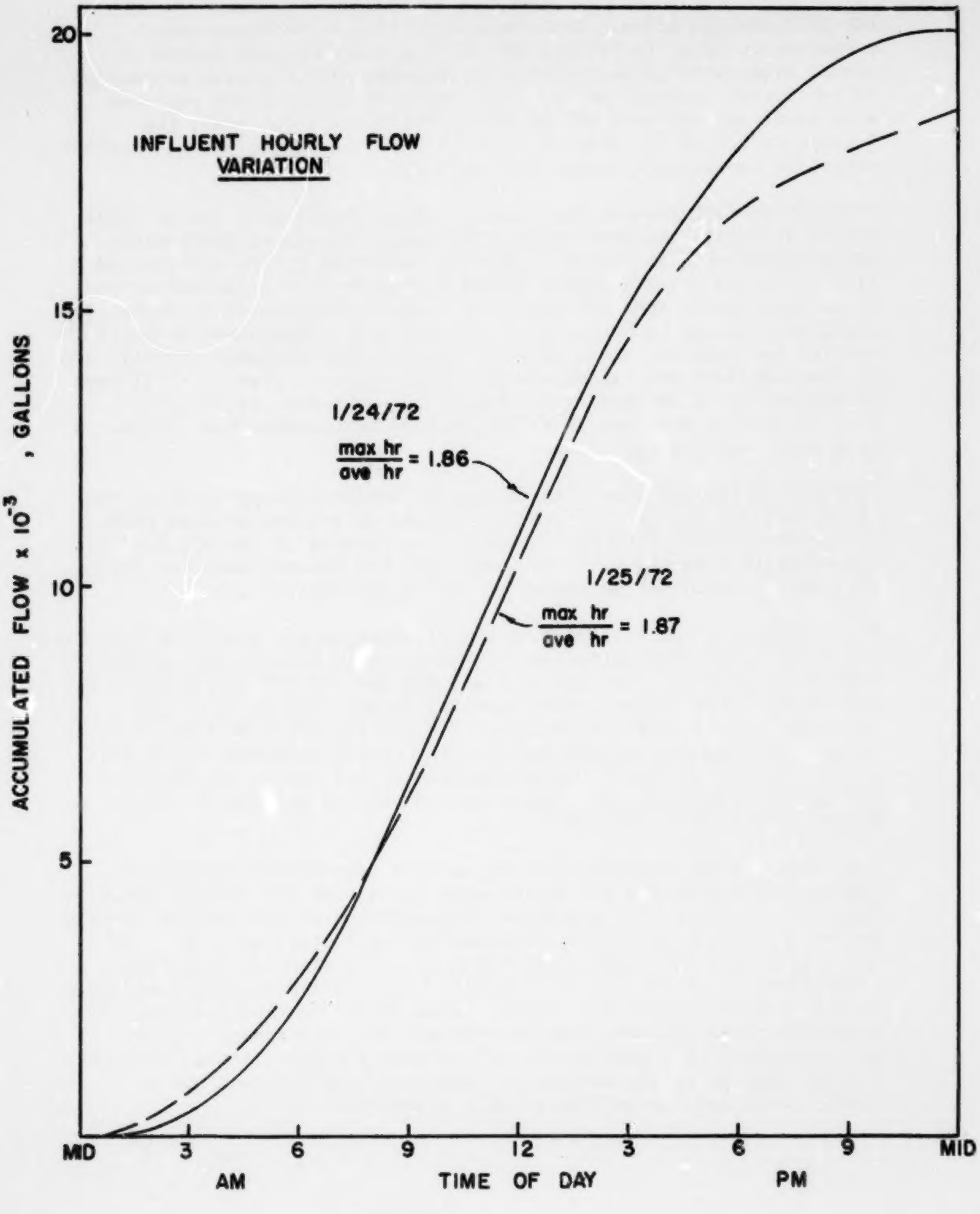


FIGURE 6

BOD 20°C determination. Both total and filtered analyses were performed in order to reflect the influence of the pond system on actual biochemical stabilization as compared with physical separation of particulate organic matter. No long-term ultimate BOD analyses were performed nor were COD or Total Carbon Analyses; thus, the interpretation of the data in terms of mass balances of oxygen demanding materials through the system was limited.

Although the BOD load to the lagoons varied widely over the one year period of study, the most apparent influence on lagoon performance was temperature. In Figure 7, BOD load and temperature are plotted along with the primary lagoon dissolved oxygen (D.O.) concentrations. It is immediately apparent that D.O. rapidly disappeared in the spring along with rising temperatures. In fact, D.O. disappeared on April 10 and did not reappear until July 19. During the remainder of July, six of thirteen days the lagoon was devoid of oxygen. Also 11 of 31 days in August, 15 of 30 days in September, 19 of 31 days in October, 6 of 30 days in November, and 2 of 31 days in December D.O. values were less than 1.0 mg/l.

It might be assumed that this increased demand for oxygen during the spring was due to the increased biological activities brought about by the warmer temperatures. However, examination of the BOD load just preceding this period would indicate that the demands measured during this period could not be accounted for by the applied load.

For example, if one assumes that the ultimate oxygen demand is 1.47 times the 5 day value (deoxygenation constant, $k_1 = 0.1$/day), the oxygen demand for an annual average of 5 day BOD load of 270 lb/day would be 397 lb/day. The oxygen demand measured in May, during the oxygen deficient period, was 1165 lbs/day, 768 lbs in excess of that predicted above. Furthermore, if one computes the oxygen supplied during this period based on a standard transfer rate of 4.0 lbs O_2 per Kw hr., approximately 600 lbs. of oxygen are transferred per day by this system at 20°C and zero D.O.

Therefore, it is reasonable to assume that significant amounts of biodegradable organics are being solubilized from the benthal deposits. During the cold months, anaerobic decomposition of the settled organic matter slows down resulting in accumulations of this material. As the temperature increases, biological activity also increases and solubilization of the benthal deposits begin to appreciably contribute to the organic load of the lagoon. This solubilization increases to a maximum value and then remains constant over the summer months. It may be assumed that this cyclic effect will continue, stabilizing the settled organic solids during the warmer periods and continue to produce both gas and soluble organic compounds.

CHEESE PROCESS WASTEWATER LAGOONS
EPA - KENT CHEESE CO.
JAN 1971 - 1972

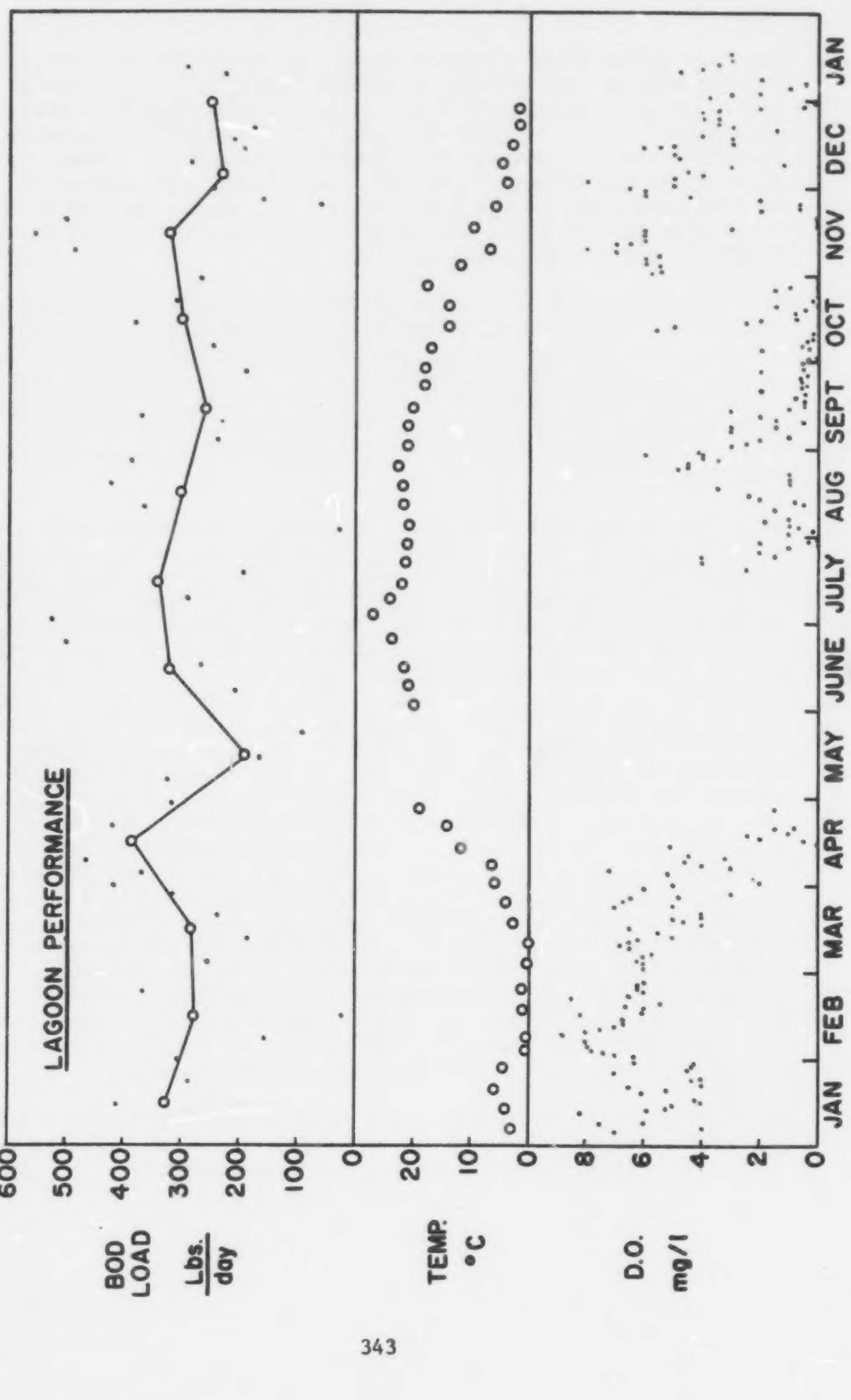


FIGURE 7

The high oxygen demands occurring during the spring in waste stabilization lagoons has been attributed to benthal digestion by a number of investigators. Marais and Capri (1970) have attempted to estimate the benthal demand in aerated lagoons. In a dynamic simulation of data collected for domestic wastewater lagoons, they showed that the rate of benthal decomposition was highly temperature dependent with an estimated value of the temperature coefficient theta of 1.35. They found that approximately 40 percent of the settled organic matter was resolubilized for the domestic waste.

The one year period of this study was insufficient to adequately quantify the benthal contribution to the lagoon organic load. The study period was too brief to evaluate the effectiveness of the anaerobic digestion in reducing accumulated sludge deposits. Steady state (or rather a quasi-steady state) may occur only after a number of years. Yet based on this and other studies, it is reasonable to report that oxygen demands during the spring may exceed three to five times the applied BOD_5 load.

Dissolved oxygen concentrations in the secondary lagoon were normally greater than 2.0 mg/l even during the April-July period of anaerobiosis in the primary lagoon. Only during two weeks in late June did dissolved oxygen levels drop below 2.0 mg/l and there was never a time when a value of zero D.O. was recorded. Dissolved oxygen concentrations were highest during the winter months, decreasing as oxygen uptakes increased in the spring and summer months.

The results of BOD analyses in the two lagoons appear by quarter in Table VI. The removal of BOD was strongly correlated with lagoon temperatures reaching a maximum late in the summer and early fall. Average BOD removal through both lagoons was 97.2 percent with the poorest performance occurring in the winter quarter with a value of 95.1 percent. During the 4 1/2 month period, July 1 through November 15, the effluent BOD did not exceed 30 mg/l and was 20 mg/l 70 percent of the time. Examination of the probability plots for total and soluble BOD in the primary and secondary lagoon effluents (Figures 8 and 9) indicates that the distributions of effluent BOD are skewed being bounded at the lower end by the presence of organic matter relatively resistant to biological degradation. Considerable scatter of effluent BOD is demonstrated above the 50 percentile suggesting that, even with very long detention times, the reliability of the system to turn out high quality effluent at all times is very improbable.

It is of interest to note that the soluble fraction of the effluent BOD represents on an average 50 percent of the total, with the highest values occurring during the spring and summer quarters.

TABLE VI

BOD ANALYSES

Kent Cheese Co. - EPA

Quarter 1971	Influent		Primary Effluent			Secondary Effluent		
	Total	Soluble	Total	Soluble	% Rem* Total	Total	Soluble	% Overall Rm. Total-
Jan-Mar.	1975	1160	263	56	86.7	98	48	95.1
Apr-June	1880	1030	204	45	89.2	61	32	96.8
July-Sept.	1530	870	122	37	92.0	21	13	98.5
Oct-Dec.	2100	1420	274	42	87.0	31	14	98.5
Aug.	1890	1140	220	45	88.4	52	27	97.2

All values of BOD in mg/1

*BOD Removal based on total BOD

CHEESE PROCESS WASTEWATER LAGOONS

EPA - KENT CHEESE CO.
JAN 1971 - 1972

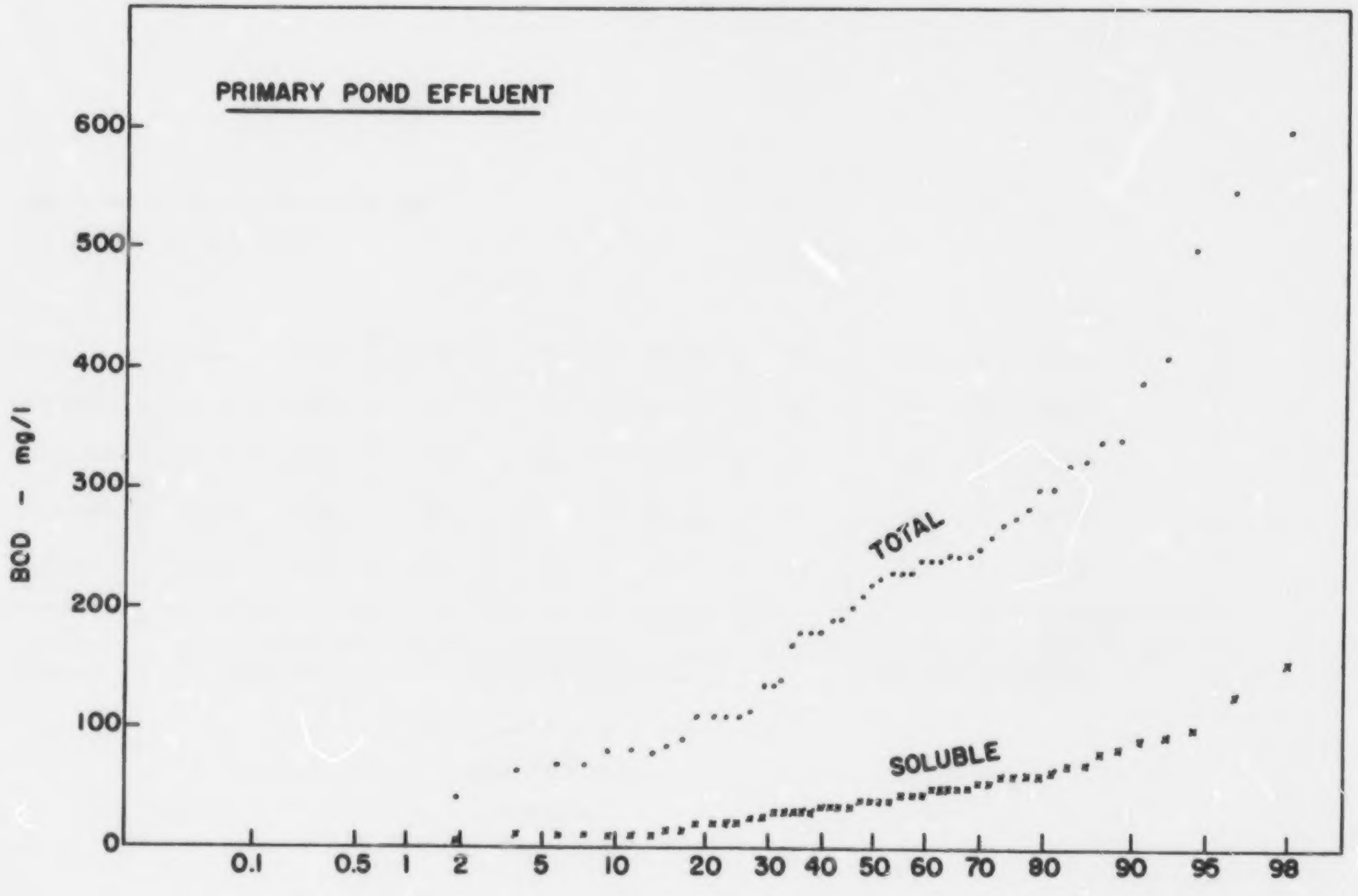


FIGURE 8

CHEESE PROCESS WASTEWATER LAGOONS

EPA - KENT CHEESE CO.
JAN 1971 - 1972

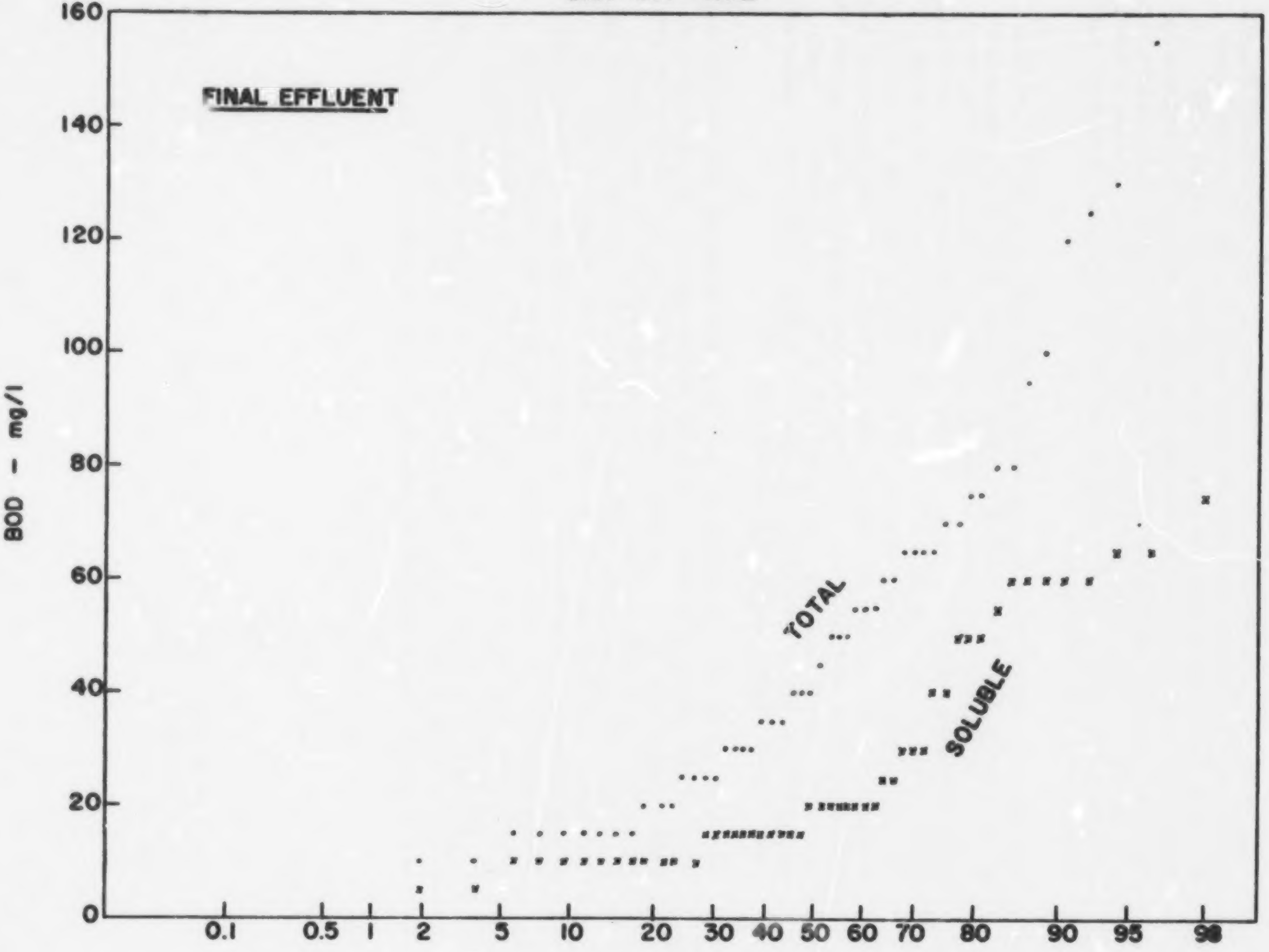


FIGURE 9

Figures 10 and 11 illustrate the variations of BOD loading and lagoon detention time throughout the one year period. The data presented are compiled from running averages of approximately seven week intervals, representing the minimum detention time in the lagoons. Percent removals were estimated by examining effluent data approximately one detention time delayed from influent data. Thus, percent removals plotted represent the mean removal during the previous detention period based on running averages.

Loadings to the primary lagoon varied from 0.93 to 1.97 lb BOD/1000 cu ft/d, and from 0.08 to 0.29 lb BOD/1000 cu ft/d in the secondary lagoon. It was not possible to detect seasonal variations of primary lagoon loading owing to the frequency of periods employed. Detention time, however, did reflect a significant seasonal variation being lowest during the summer months. Examination of Figures 10 and 11 suggest the advantages of staged lagoon operation. The secondary lagoon definitely attenuated final effluent BOD concentrations throughout the year even though primary lagoon effluents fluctuated widely. Again, percent removals were apparently more dependent upon lagoon temperature than either lagoon loading or detention time.

BOD Removal Rates - In order to quantify the observed BOD removal data with lagoon detention time, a kinetic model was derived employing a mass balance analysis. Because temperature directly affects the reaction rate coefficient and because the detention periods in the lagoons were long, no attempt was made to ascertain the precise order of the reaction. Furthermore, oxygen dispersion data suggested that the primary lagoon was well mixed, at least with respect to soluble BOD. Finally, since volatile suspended solids were not correlated with active biomass, no effort was made to employ a term for active biomass in the kinetic expression. Based on these rather broad boundary conditions, a relatively simple model was developed. Assuming a completely mixed configuration, removal of BOD as a first order function in BOD, and a steady state condition, the following expression is derived:

$$QL_o - QL_e - kVL_e = 0 \qquad (1)$$

$$\text{and } k = \frac{L_o - L_e}{L_e t}, \qquad (2)$$

where k is the first order removal rate of BOD, 1/days, t is detention time, V/Q days, and L_o and L_e are the BOD_5 concentrations, mg/l, in the influent and effluent, respectively. A temperature correction

CHEESE PROCESS WASTEWATER LAGOONS

EPA - KENT CHEESE CO.

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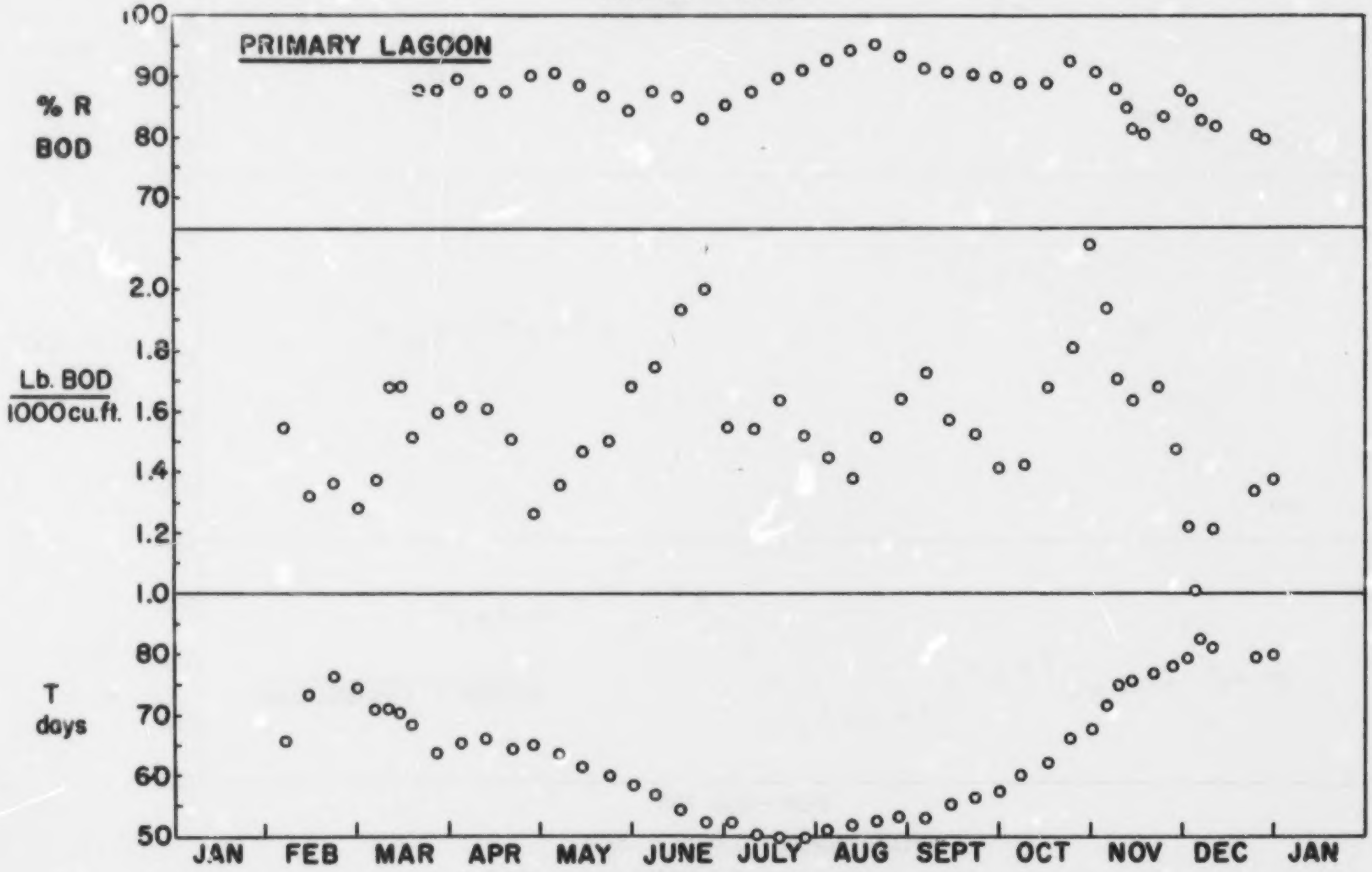

FIGURE 10

CHEESE PROCESS WASTEWATER LAGOONS

EPA – KENT CHEESE CO.

JAN 1971 – 1972

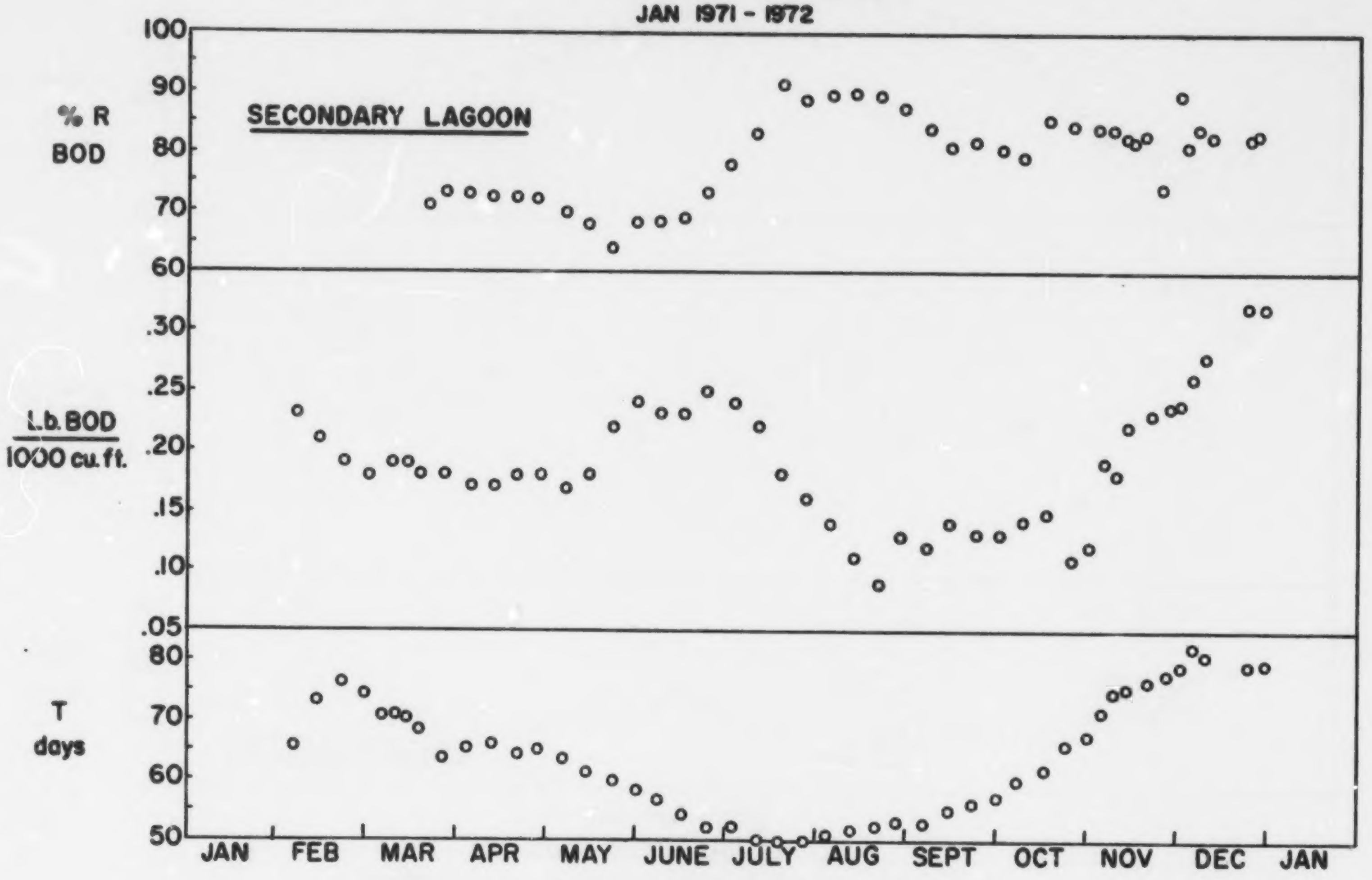

FIGURE 11

for k may be obtained from the expression

$$k_{T_1} = k_{T_2} \theta^{T_1 - T_2} \qquad (3)$$

where k_{T_1} and k_{T_2} are the reaction rate coefficients at temperatures T_1 and T_2 respectively, T is temperature in °C and θ is the temperature coefficient.

Values of k were calculated from the data based on running averages and are presented in Figures 12 and 13. It is apparent that the values of k are dependent upon lagoon temperatures. The increases in k during the early spring may also be due to the resolubilization of degradable organic matter from the benthal deposits. It is difficult to assess, however, the reason for the very high increases in k noted in late July and early August. Careful examination of the data indicates that the lowest effluent BOD concentrations were recorded at this period, yet seven weeks earlier (when influent BOD values were used to calculate values of k) influent BOD values were high. Thus, slight shifts in the selection of influent and effluent data for calculation of k values greatly affected the average value of k during that period.

The soluble BOD removal rates were considerably higher than total removal rates suggesting that a significant portion of the insoluble BOD is more resistant to rapid decomposition. It is also apparent that the secondary lagoon reaction rates are usually lower than those in the primary lagoon. In general, the removal rates for soluble BOD in the secondary lagoon were almost one order of magnitude lower than for the primary lagoon whereas the total BOD removal rates in the secondary process approached those in the primary lagoon during certain periods of the year.

The influence of temperature on the rate of BOD removal is presented in Figures 14 and 15. There are strong correlations between temperature and total BOD removal rates in the primary lagoon as depicted in these figures. A least squares fit of the data for total BOD indicates that theta has a value of 1.085 for the primary lagoon and 1.026 for the secondary lagoon. These values are within the range normally reported for aerated lagoon systems. The rate of removal of BOD appears less sensitive to temperature in the secondary lagoon because of differences in the availability of organic matter going to that lagoon. Less readily available organic matter discharged during the summer months may conceivably result in lower rates of stabilization than during the winter period. Also, this is evident for soluble BOD (Figure 15) where it was not possible to evaluate a temperature coefficient for the secondary lagoon.

CHEESE PROCESS WASTEWATER LAGOONS

EPA - KENT CHEESE CO.
JAN 1971 - 1972

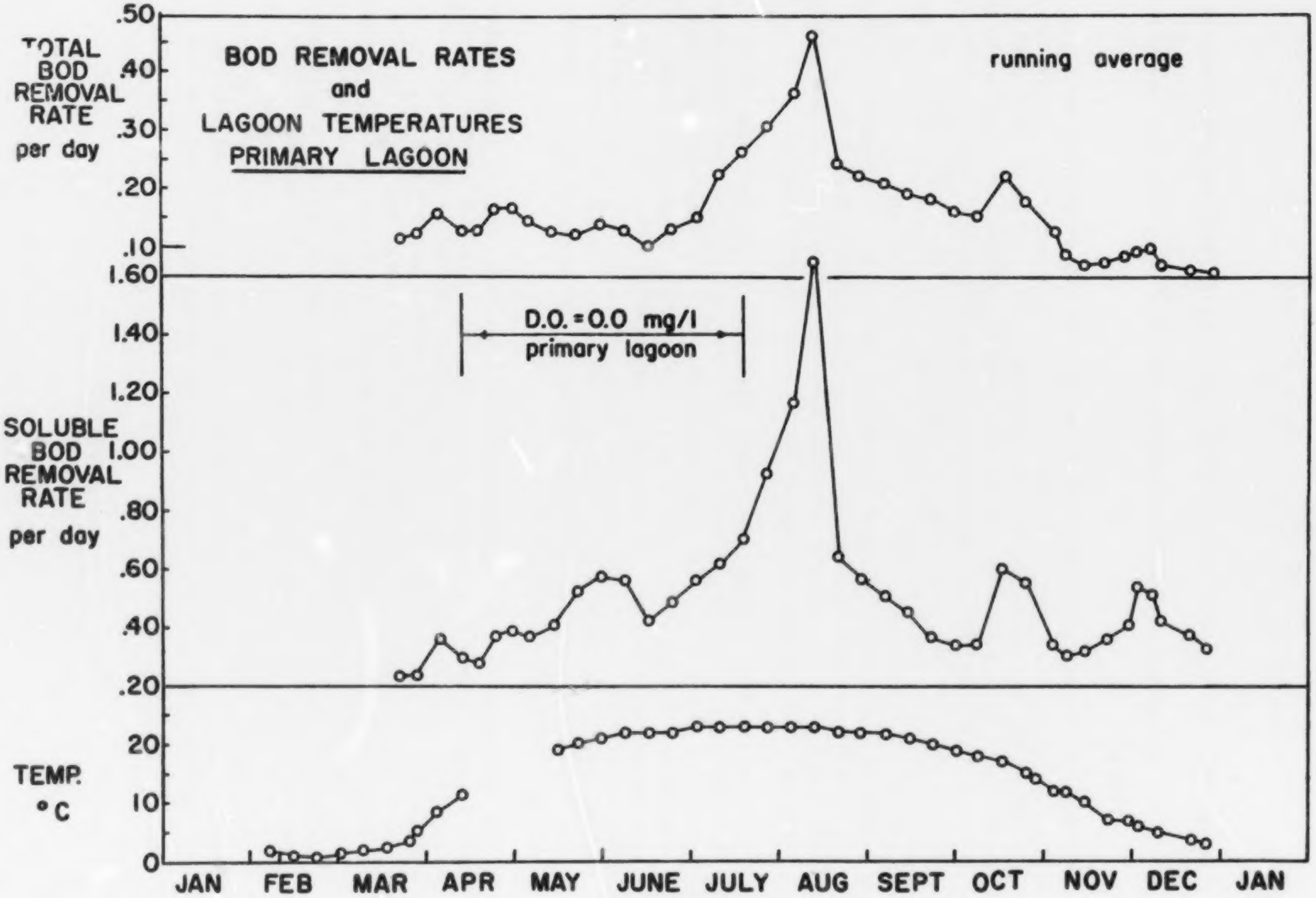

FIGURE 12

CHEESE PROCESS WASTEWATER LAGOONS
EPA - KENT CHEESE CO.
JAN 1971 - 1972

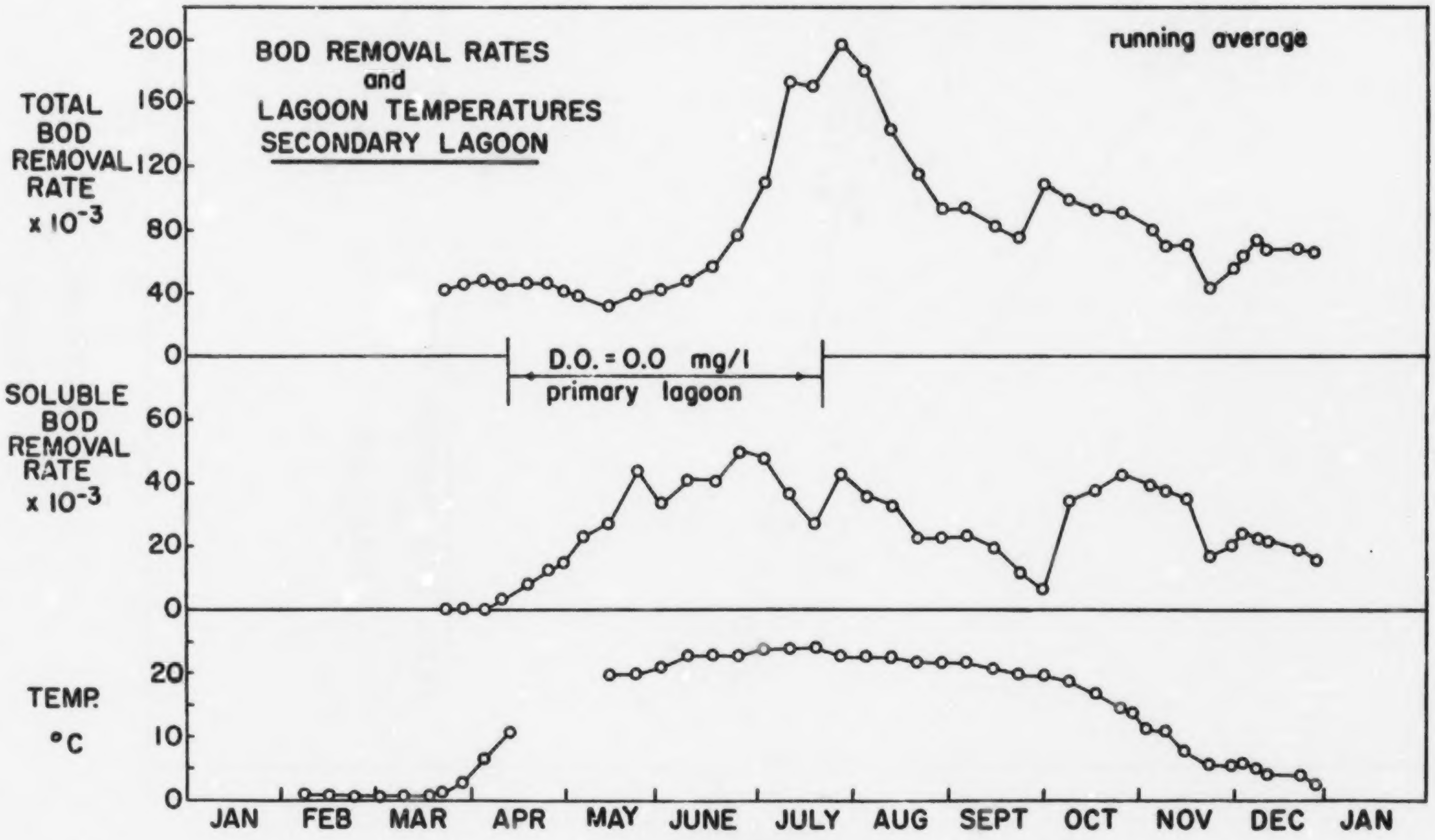

FIGURE 13

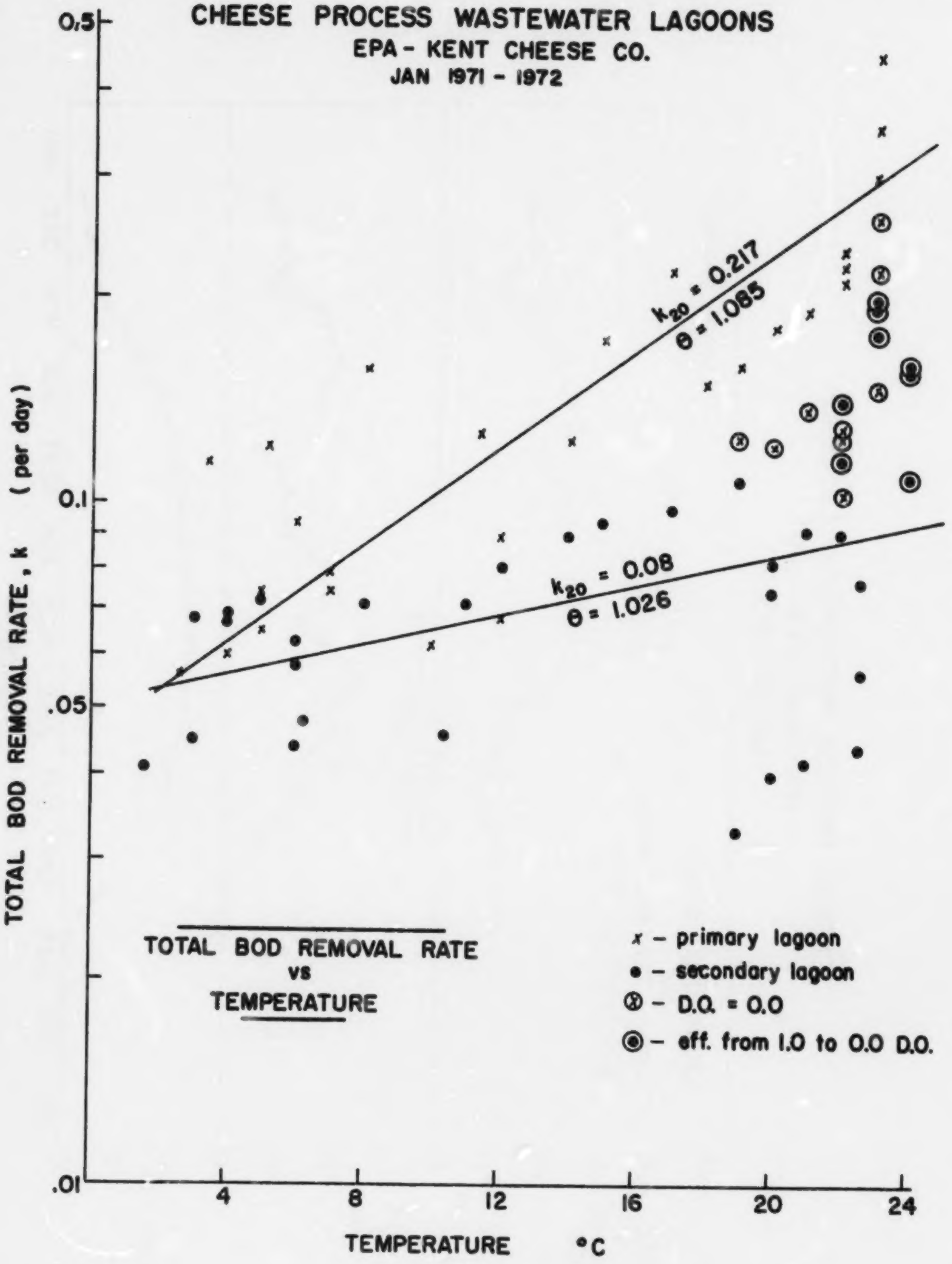
CHEESE PROCESS WASTEWATER LAGOONS
EPA - KENT CHEESE CO.
JAN 1971 - 1972
0.5
0.1
.05
.01
TOTAL BOD REMOVAL RATE, k (per day)
4
8
12
16
20
24
TEMPERATURE °C
k20 = 0.217
θ = 1.085
k20 = 0.08
θ = 1.026
TOTAL BOD REMOVAL RATE
vs
TEMPERATURE
x - primary lagoon
● - secondary lagoon
⊗ - D.O. = 0.0
◉ - eff. from 1.0 to 0.0 D.O.

FIGURE 14

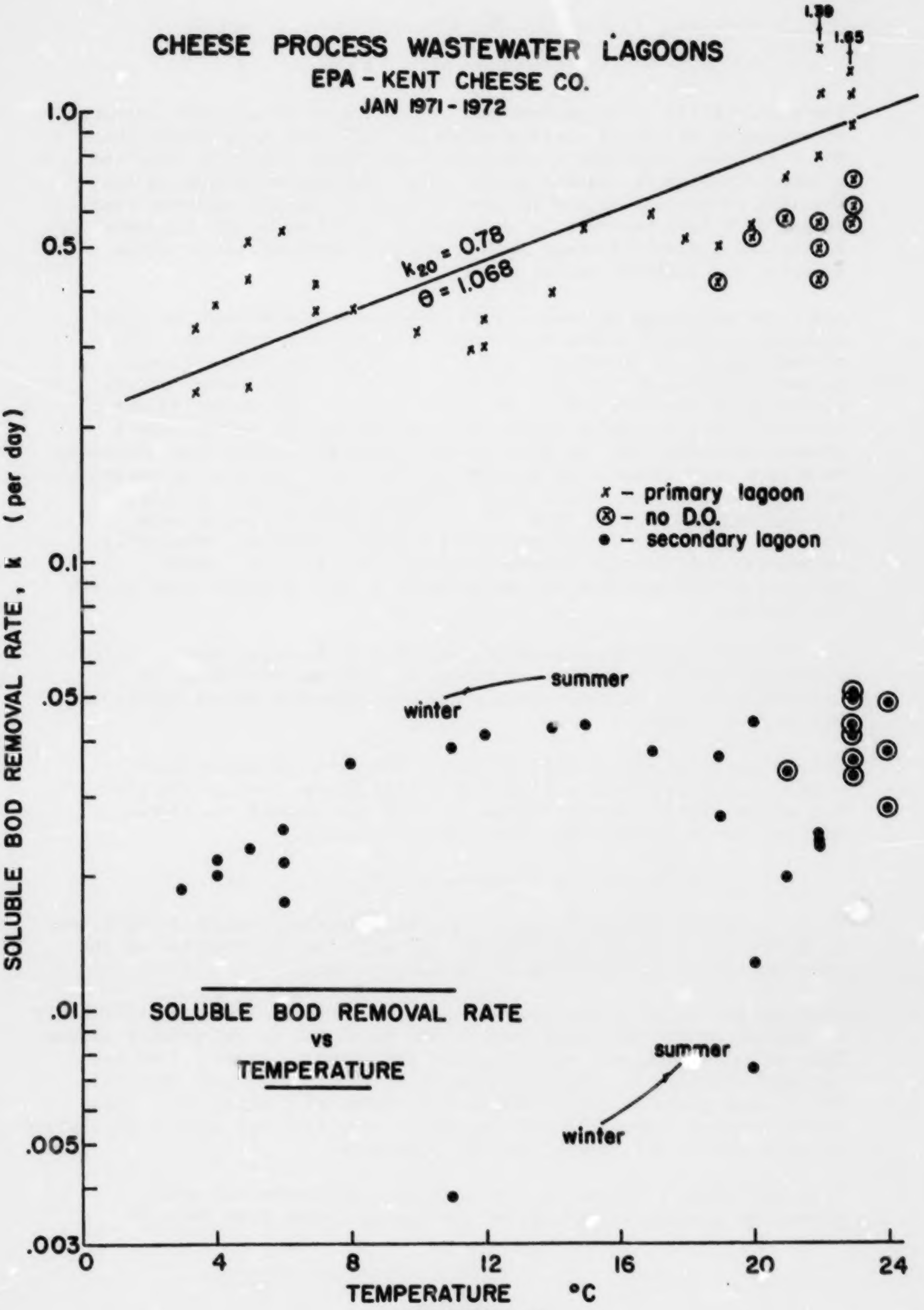
CHEESE PROCESS WASTEWATER LAGOONS
EPA - KENT CHEESE CO.
JAN 1971 - 1972
1.39
1.65
$k_{20} = 0.78$
$\theta = 1.068$
x – primary lagoon
⊗ – no D.O.
● – secondary lagoon
summer
winter
summer
winter
SOLUBLE BOD REMOVAL RATE
vs
TEMPERATURE
SOLUBLE BOD REMOVAL RATE, k (per day)
1.0
0.5
0.1
.05
.01
.005
.003
0
4
8
12
16
20
24
TEMPERATURE °C

FIGURE 15

Suspended Solids - The performance of the lagoon system with respect to suspended solids is considerably more difficult to quantify than BOD. Influent suspended solids were high (Table VII) and contained a large fraction of organic matter. Data was not available on the settling properties of the influent solids and it was apparent that suspended solids removals in the primary lagoon were very sporadic. During the oxygen deficient period, primary effluent solids often exceeded the influent solids level.

Again the advantage of staged lagoon operation was evident as final effluent suspended solids were considerably more attenuated. The probability plots (Figures 16 and 17) indicate that the effluent suspended solids are not distributed normally, being rather widely scattered at the high end of the distribution. The lowest values of final effluent suspended solids occurred during the period July 1 through September 19. In this period, suspended solids concentrations were less than 50 mg/l, 60 percent of the time. The average suspended solids concentration in the final effluent was 108 mg/l of which 91% was volatile matter (Table VII). It is interesting to note that the solids discharged were predominately volatile, especially during the July through December period. Furthermore, lowest effluent solids occurred during the period when greatest algal growth was evident.

The effluent discharge structure, as noted previously, was a vertical standpipe with no baffling. Although no data was available, it is reasonable to assume that baffles may significantly reduce suspended solids discharges.

Solids Contributions to Effluent BOD - The data presented above suggests that suspended solids play a significant role in the biodegradable organic matter discharged from the lagoons. A simple mathematical expression for this contribution is:

$$L_e(\text{total}) = L_e(\text{soluble}) + C\ S_e, \qquad (4)$$

where S_e is the concentration of volatile suspended solids in mg/l, and L_e is the total or soluble BOD_5 in mg/l and C is the fraction of the volatile solids contributing to the BOD_5 (total).

Although not well correlated, there was an indication that approximately 62 percent of the VSS contribute to the total BOD in the primary lagoon. This value is high and indicates that the primary lagoon solids are not well stabilized. The contribution of VSS to the final effluent BOD is also quite variable, the average value of C being 0.2. This value is quite reasonable for lagoons of this type and algal contributions to total BOD in this range are well documented.

Nutrient Levels - The nutrients, nitrogen and phosphorus were determined monthly on composited samples collected from the raw

TABLE VII

SUSPENDED SOLIDS ANALYSES

Kent Cheese Co. - EPA

Quarter	Influent		Primary Effluent			Secondary Effluent		
	Total	Volatile	Total	Volatile	% Remov. (Total)	Total	Volatile	% Overall Removal (Total)
Jan-Mar.	658	614	403	335	38.6	155	143	73.4
Apr-June	600	569	477	390	20.5	119	103	80.1
July-Sept.	547	520	239	197	56.3	43	43	92.1
Oct-Dec.	595	565	445	377	25.2	111	110	81.3
Avg.	602	567	395	328	34.4	108	98	82.0

All values of suspended solids in mg/l

*S.S. removal based on T.S.S.

CHEESE PROCESS WASTEWATER LAGOONS

EPA - KENT CHEESE CO.
JAN 1971 - 1972

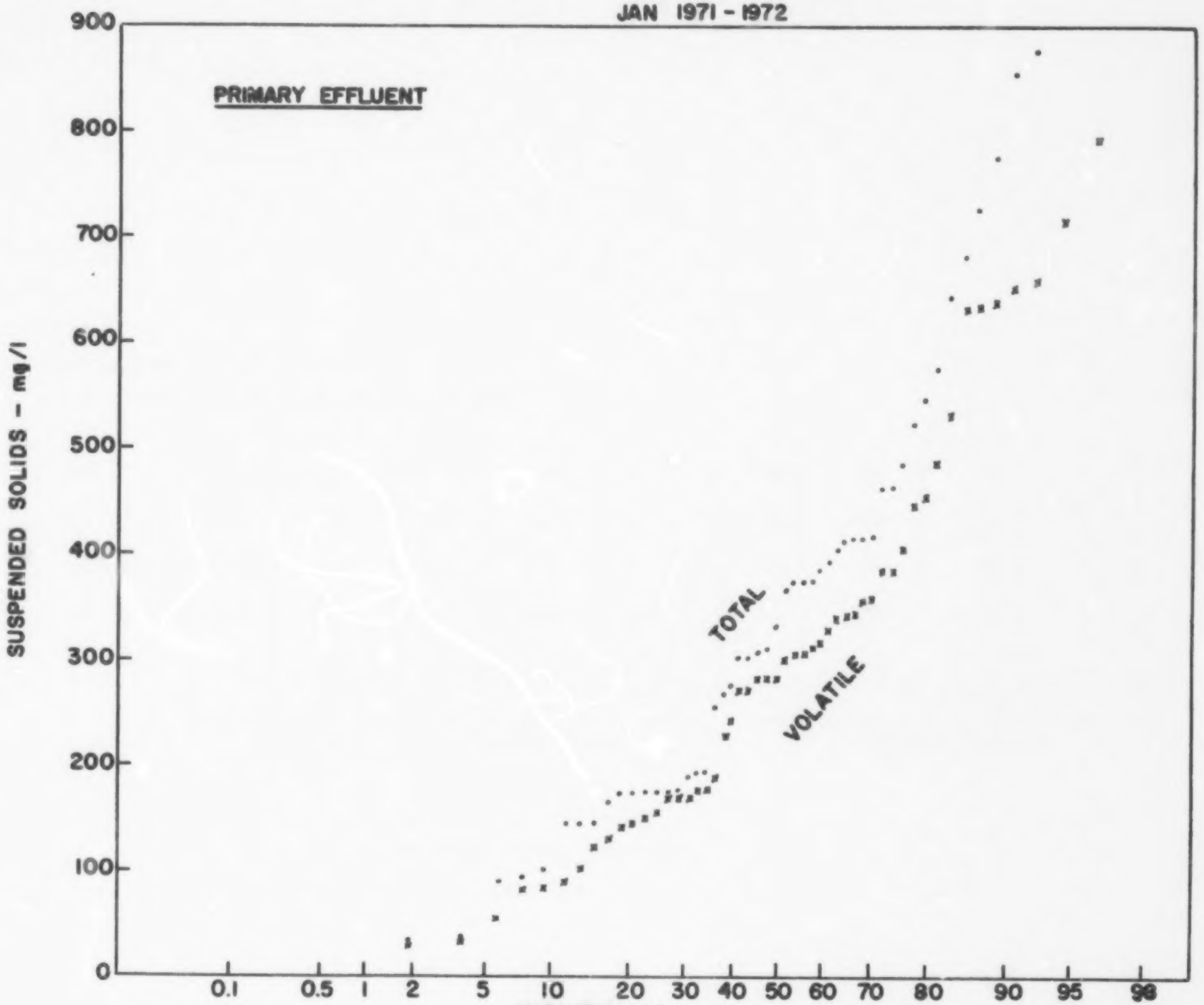

FIGURE 16

CHEESE PROCESS WASTEWATER LAGOONS
EPA - KENT CHEESE CO.
JAN 1971 - 1972

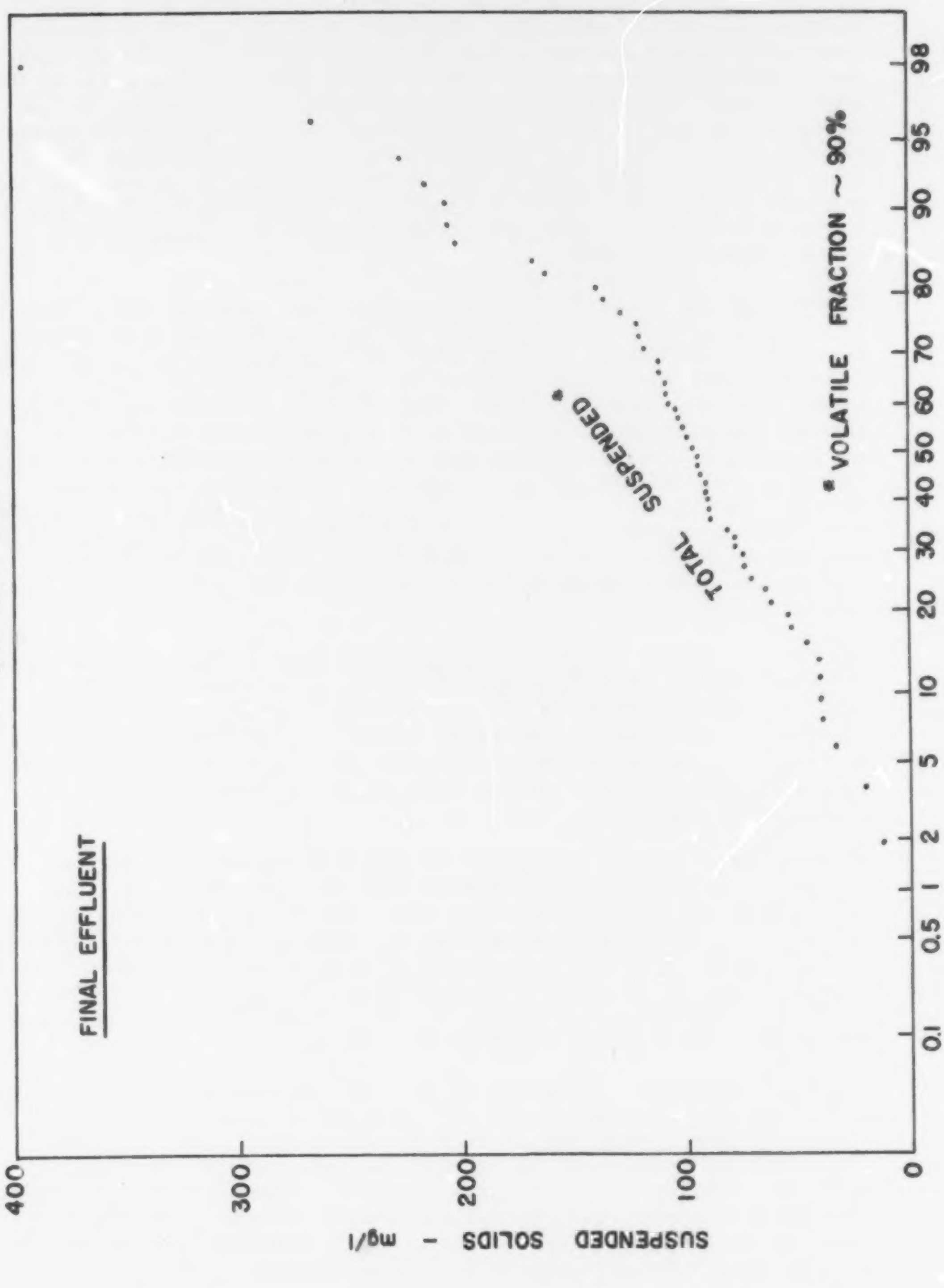

FIGURE 17

wastewater stream and the secondary lagoon. The results of these analyses appear in Table VIII. Examination of Table VIII indicates that total phosphorus levels are high owing to the use of phosphate base cleaners. A substantial amount of phosphorus was removed in the pond system. It should be emphasized, however, that removal is the result of sedimentation of the phosphorus and that eventually substantial amounts of phosphorus will be resolubulized and be discharged in the final effluent. Thus, during the one year period, it is doubtful that a steady state with respect to phosphorus transformations has been achieved and, likely, effluent levels may rise significantly over those presently reported.

No data was available on the ammonia nitrogen levels in the system, but it is apparent that total Kjeldahl nitrogen is very low with respect to carbon. The BOD to Nitrogen ratio for the raw wastewater averaged 100:0.53, well below that normally required for adequate biological growth (100:5). The substantial removals of total Kjeldahl nitrogen through the pond system is indicative of both cell synthesis and sedimentation. It is expected that nitrogen recycle would play an important role in the biological system in these lagoons. Nitrate nitrogen in the final effluent was normally low, but warmer temperatures did result in significant nitrification between May and September. An examination of lagoon temperature during these months (Figure 12) indicate that when temperatures exceeded 20°C the rates of nitrification did increase.

Coliform and Fecal Coliform - The sanitary wastewaters from the cheese processing plant were discharged to the process sewers, thereby requiring the installation of chlorination equipment for disinfection of the final effluent. Both total and fecal coliforms were determined from flow composited samples of the raw wastewater and final effluent preceding disinfection. During this study, no chlorination of the effluent was practiced.

Examination of Figure 18 indicates that better than 99.9 percent of the total coliforms was achieved in the lagoons. Similarly, fecal coliform counts which ranged from less than 10^3 to as high as 10^7 per 100 ml were reduced by greater than 99.9 percent throughout the study period. Temperature did not appear to significantly influence coliform disappearance in the lagoons during the survey period. In fact, although there was considerable variation in effluent coliform numbers, there was no apparent trend in disappearance rates.

Other Measurements - Values of pH and alkalinity were measured routinely throughout the one year study. Raw wastewater pH values were highest during January through May, averaging approximately 6.6, and then decreased and leveled off to 6.2 for the remainder of the study. Similarly alkalinities of the raw wastewater averaged 350 mg/l during the January through April period and then continuously decreased to approximately 220 mg/l in September. It is possible that process changes or raw water quality accounted for these changes.

TABLE VIII

NITROGEN AND PHOSPHORUS

EPA - Kent Cheese Co.

Date 1971	Day	Influent					Effluent				
		Total Phosphorus		Total Kjeldahl Phos.		Nitrate Nitrogen	Total Phosphorus		Total Kjel-dahl Phosph.		Nitrate Nitrogen
		mg/1	lb/d	mg/1	lb/d	mg/1	mg/1	lb/d	mg/1	lb/d	mg/1
1-22	F	37.0	8.5	7.5	1.7	0.1	35.0	8.0	4.0	0.9	0.3
2-23	Tu	35.0	4.1	9.2	1.1	1.0	27.5	3.3	5.9	0.7	0.5
3-19	F	41.3	4.9	10.8	1.3	0.1	26.4	3.1	5.5	0.7	0.2
4-12	M	7.4	0.7	10.2	1.0	0.4	28.0	2.8	6.0	0.6	0.4
5-14	F	32.5	5.4	5.3	0.9	0.4	26.8	4.5	10.6	1.8	1.9
6-15	Tu	76.9	13.2	16.0	2.7	4.4	10.7	1.8	4.2	0.7	24.4
7-9	F	15.5	3.1	12.2	2.4	0.1	14.8	2.9	1.5	0.3	3.4
8-10	Tu	33.0	5.8	3.6	0.6	0.1	11.6	2.0	1.0	0.2	4.0
9-11	Sa	68.4	14.0	12.1	2.5	0.1	8.4	1.7	1.1	0.2	1.4
10-13	W	55.7	8.2	2.0	0.3	0.1	14.8	2.2	0.2	0.0	0.4
11-14	Su	04.6	14.4	26.2	3.9	0.1	23.1	3.5	1.8	0.3	0.4
12-16	Th	42.6	5.7	7.7	1.0	2.7	31.6	4.3	4.2	0.6	0.2
Avg.		45.0	7.3	10.2	1.6	--	21.6	3.3	3.8	0.6	--

BOD: N:P = 1900: 10.2: 45.0
= 100: 0.53: 2.46

CHEESE PROCESS WASTEWATER LAGOONS

EPA - KENT CHEESE CO.

JAN 1971 - 1972

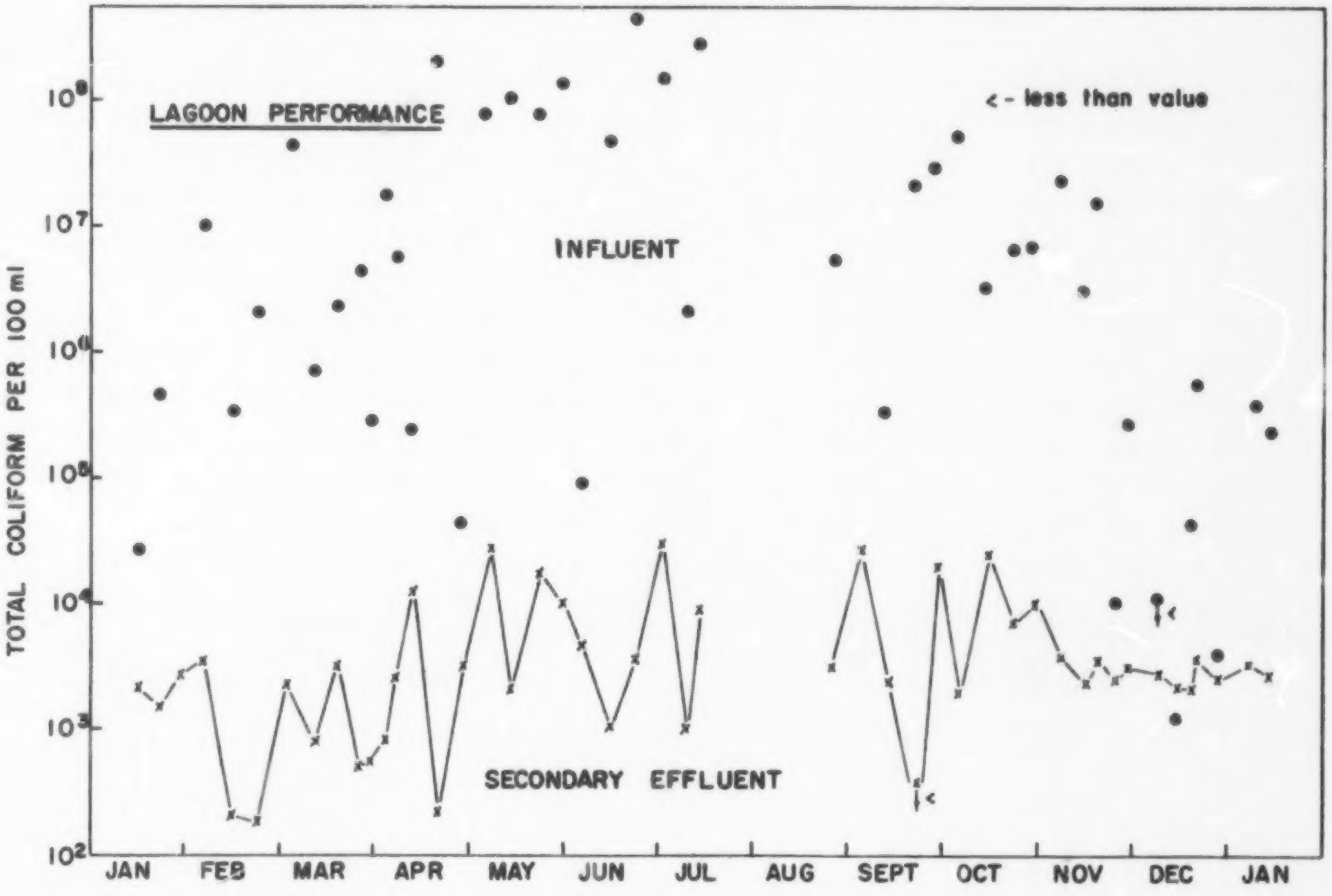

FIGURE 18

The lagoons exhibited higher pH values (7.4 to 7.5), being the highest during the first one half of the year (January through June), and then sharply decreased to a value of 7.2 for the remainder of the study. Alkalinities ranged from about 380 mg/l to as high as 510 mg/l during the year. No correlation was noted between pH and measured alkalinity and there was no particular trend in alkalinity values during the year. It is assumed that changes in algal activities and microorganism respiration influenced these variations, but no data was available on algal activities to document these variations.

Settleable solids were monitored daily on the raw wastewater and on the primary and secondary lagoon effluents. Settleable solids in the raw wastewater ranged between 0.1 and 5 ml/liter during the one year study, normally being less than 1.0. Secondary lagoon effluents never demonstrated significant amounts of settleable solids, but the primary lagoon effluent was high in settleable solids from mid-May through mid-July. Values as high as 120 ml/liter were recorded during this period when dissolved oxygen concentrations were zero. Floating mats of solids and rising sludge were noted throughout this period. Once dissolved oxygen was maintained in this lagoon, the settleable solids decreased to an immeasureable amount.

Cost - The annual costs associated with the Kent Cheese Co. wastewater treatment facilities are based on operating and maintenance costs consisting of electric power requirement, repairs, operator costs, and administration. Annual capital costs are based on an interest rate of 7 1/2 percent for mechanical and equipment amortized over a five year period and costs associated with lagoon construction over a 30 year period. The annual costs do not include those costs associated with the post construction studies which are not representative of normal operating expenses. A summary of the costs related to annual operation of these treatment facilities are presented below:

Construction Costs		Annual Costs
Contract	$29,097.10	
Engineering		
Pre Construction Report	500.00	
Plans	3,387.14	
Construction Superv.	916.00	
sub total	$33,900.24	
(i = 7.5% 30 yr)		$2,870.00
Mechanical Equipment	14,807.18	
(i = 7.5% 5 yr)		3,661.00
	sub total	$6,531.00
Operating and Maintenance Costs		
Electric Power		$2,477.71
Repairs		2,969.00
Operator		1,254.33
Administration		144.60
	sub total	$6,845.64
Total Annual Costs		$13,376.64

These cost estimates were prepared for a period of operation soon after construction was completed and the operating costs reflected in the category of repairs may be higher than may be expected on an average basis. In addition, the costs for analytical services in conjunction with the post construction studies were not included in the cost estimate but some additional operating costs will be necessary for routine chemical analysis necessary for reporting to regulatory agencies. Thus, it is expected that these two factors may tend to compensate each other and the estimate provided is indicative of costs associated with this treatment method.

The annual cost prorated to pound of BOD applied or 1000 gallons of wastewater treated are $0.14 per pound of BOD and $2.15 per thousand gallons respectively. Based on cheese produced, the annual cost is approximately 0.33¢ per pound.

CONCLUSIONS

The conclusions summarized below are the result of the analysis of data collected over a one year period from the two-stage aerated lagoons treating cheese processing wastewaters for the Kent Cheese Company.

Each of the two lagoons are of equal volume and provided detention times of from 50 to 82 days each during the first year of study. The average flow to the lagoons was 17,000 gal/day providing a BOD_5 loading of 270 lbs/day. Organic loading to the primary lagoon varied from 1.0 to 2.6 lbs/1000 cu ft/day.

1. Aerator Performance
   a. The oxygen transfer efficiency of the Polcon Corporation Helixors in the primary lagoon was 4.0 lbs oxygen/kw-hr or 3.0 lbs oxygen/hp-hr, for standard conditions (20°C tap water, zero dissolved oxygen) at an air flow rate of 14.8 scfm per unit.

   b. Doubling the air flow rate per unit substantially reduced the oxygen transfer efficiency.

   c. The dispersion of oxygen in the primary lagoon at a power input of 8.5 hp/MG was nearly uniform.

   d. At the power input of 8.5 hp/MG, there was a tendency for suspended solids to accumulate in the peripheral regions where horizontal velocity components were normally less than 0.1 fps. The one year study was not long enough to evaluate fully the rate of solids accumulation within the lagoon.

   e. The relative oxygen transfer coefficient in the primary lagoon was approximately 81 percent of that expected in tap water. The oxygen saturation value in the primary lagoon content was approximately 98 percent of that in pure water.

2. Lagoon Performance
   a. An average of 97.2 percent removal of BOD_5 was achieved in the two stage aerated lagoon system with the poorest performance (95.1 percent) occurring during the winter season. The average final effluent BOD_5 concentration was 52 mg/l of which 27 mg/l was soluble. Probability distributions for treatment performance were prepared for the one year study.

b. A simplified model of lagoon performance was derived based on complete mixing in the lagoon and first order removal of BOD_5.

c. Temperature had a significant effect on lagoon performance. Values of the temperature coefficients for BOD removal rates were graphically determined for both primary and secondary lagoons.

d. Suspended solids removals in the primary lagoon were sporadic. The overall average removal of suspended solids in the lagoon system was 82 percent with an average concentration of 108 mg/l in the final effluent. Over 90 percent of the suspended solids were volatile.

e. Approximately 20 percent of the volatile suspended solids in the final effluent contributed to the total BOD_5. A similar relationship for the primary effluent suspended solids indicated that 62 percent of the volatile suspended solids contributed to the BOD_5.

f. High oxygen uptake rates occurring in the early spring resulted in zero D.O. concentrations in the primary lagoon. These high uptake rates are likely due to the solubilization of solids deposited during the winter months. The cycling of sludge accumulation during the cold periods and active biological stabilization of the benthal deposits during the warmer months will result in dynamic fluctuations in oxygen requirements and sludge deposits. Aerator sizing to account for these fluctuations must be provided. In this study oxygen demands in excess of four times the BOD_5 were measured during the early spring.

g. The staging of the watewater treatment lagoons provided considerable attenuation of the fluctuating BOD and solids concentrations in the primary lagoon effluent.

h. Total and fecal coliform reductions exceeded 99.9 percent in the two stage lagoon system.

i. Nitrogen concentrations in the raw wastewater were low with respect to carbon. The BOD to Nitrogen ratio was 100:0.53 indicating a substantial deficiency in nitrogen. Phosphorus concentrations were high resulting in a BOD:P ratio of 100:4.5.

j. Total phosphorus removals of 52 percent observed during the one year study may be misleading insofar as a steady state with respect to phosphorus transformations has probably not been established. Total organic nitrogen removal of 47 percent were observed. Nitrate concentrations in the final effluent were highest during the warm summer months but were less than 0.4 mg/l during the rest of the year.

3. Costs

The unit cost for wastewater treatment during the first year of operation was $2.15 per 1000 gal., $0.14 per lb BOD applied, and $0.0033 per lb of cheese produced.

RECOMMENDATIONS

Based on the operation of the two stage cheese processing wastewater lagoons at Kent, Illinois, the following recommendations have been proposed:

1. Efforts should be made to further reduce the settleable solids input to the lagoons. These solids cause clogging problems at the inverted siphon, interfere with flow measurement and sampling at the primary lagoon and result in increased BOD loading to the primary lagoon. Insofar as solubilization of settleable solids during the warm months has resulted in severe depressions in dissolved oxygen concentrations in the primary lagoon, every measure taken to reduce influent settleable solids will help to alleviate that problem. It is suggested that a settling tank or Imhoff tank be provided ahead of the primary lagoon for this purpose.

2. The high air pressures observed during dual compressor operation suggests that the air headers and inlet orifices are undersized for the increased air flow rates. Since oxygen uptake rates during the spring and early summer exceed current oxygen transfer rates, it is recommended that investigations be made to determine the necessity for enlarging existing air piping or providing additional Helixors in the primary lagoon.

3. The increased oxygen uptake rates in facultative aerated lagoons during the spring have been reported by a number of investigators. Further investigation should be conducted to provide a quantitative estimate of this increased demand. Such a study would require data collection over a number of years at the existing aerated lagoon site.

4. Nitrogen deficiencies in the raw wastewater will normally result in poorer performance of the biological system. It is recommended that additional nitrogen be added as ammonia or urea to more closely approximate the BOD to Nitrogen ratio of 100 to 5. Comparisons in lagoon performance should be noted during this period (at least one full year) so as to evaluate the value of this supplimentation.

5. The secondary lagoon effluent structure consists of only an upturned 4 inch cast iron pipe elbow. It is recommended that this effluent structure be modified so as to provide some baffling to eliminate gross solids and scum entrainment.

ACKNOWLEDGEMENTS

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APPENDIX A

Calculation of Oxygen Transfer Rate

November 19, 1970

Lagoon No. 1 (Primary Lagoon)

Average Oxygen Uptake Rate = 2.05 mg/l/hr = 17.8 lb/hr
Temp. = 6.3°C
Dissolved Oxygen = 2.9 mg/l
1 compressor - 30 amps at 220 v = 6.6 kw
Air Distribution to Primary Lagoon - 80%

Field Transfer:

$$N_f = \frac{17.8 \text{ lb/hr}}{6.6 \text{ kw} \times 0.8} = 3.32 \text{ lb/kw-hr}$$

Standard Transfer:

$$N_s = N_f \frac{C_s}{(C_s - C)\,\theta^{T-20}}$$

$$C_s \text{ at } 20°_C = 9.2\left(\frac{P_b}{29.4} + \frac{O_t}{42}\right)$$

$$= 9.2\left(\frac{14.7 + 12/2.3}{29.4} + \frac{18.3}{42}\right)$$

$$C_{s_{20°}} = 9.2\ (0.68 + 0.5)$$

$$= 10.8 \text{ mg/l}$$

$$C_{s_{6.3°C}} = 14.8 \text{ mg/l @ 12' depth}$$

$$\alpha = 0.75,\quad \beta = 0.96,\quad \theta = 1.02$$

$$N_s = 3.32\left[\frac{10.8}{[0.75(0.96 \times 14.8 - 2.9)\,1.02^{6.3-20}}\right]$$

$$N_s = 5.55 \text{ lb/kw-hr}$$

$$N_s = 4.14 \text{ lb/hp-hr}$$

*where depth = 12' and estimated transfer efficiency is 10%

CHARACTERIZATION AND TREATMENT OF BREWERY WASTES

by

Henry G. Schwartz, Jr.* and Richard H. Jones**

INTRODUCTION

The brewing industry in this country has grown steadily in recent years, with total production in 1971 amounting to 135 million barrels (Mbbl) (1). A marked change in the character of the industry has accompanied this growth. Where the industry once consisted of many small local breweries, it is now increasingly dominated by a relatively small number of regional and national brewers. Most of the small breweries have either been absorbed by the larger firms or have ceased operating entirely in the face of strong competition.

As the nature of the industry has changed, so have the individual breweries. The smaller facilities are inefficient and the cost of modernization is prohibitive. These breweries are being abandoned and new plants with much greater capacities are being constructed. Twenty years ago there were only a few breweries with capacities over 1.0 Mbbl/year while today virtually every new brewery has a capacity in the range of 1.5 to 4.0 Mbbl/year.

This trend to larger breweries creates fewer, but much more substantial waste sources. These high-volume, high-strength wastes give rise to difficult pollution abatement problems, particularly in view of increasingly stringent effluent standards.

The purpose of this paper is two-fold, first to review brewery waste treatment practices throughout the country and, secondly, to present the results of pilot plant studies at one specific location. In so doing, it is hoped that future brewery waste treatment designs will benefit from past experiences.

WASTE CHARACTERISTICS

Brewery effluent can generally be characterized as high-strength organic wastes with moderately high suspended solids concentrations. The wastes are generated from a number of plant operations as indicated in the accompanying flow diagram, Figure 1.

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*Head, Environmental Engineering, Sverdrup & Parcel and Associates, Inc., St. Louis, Missouri
**Vice President, Environmental Engineering, Inc., Gainesville, Florida

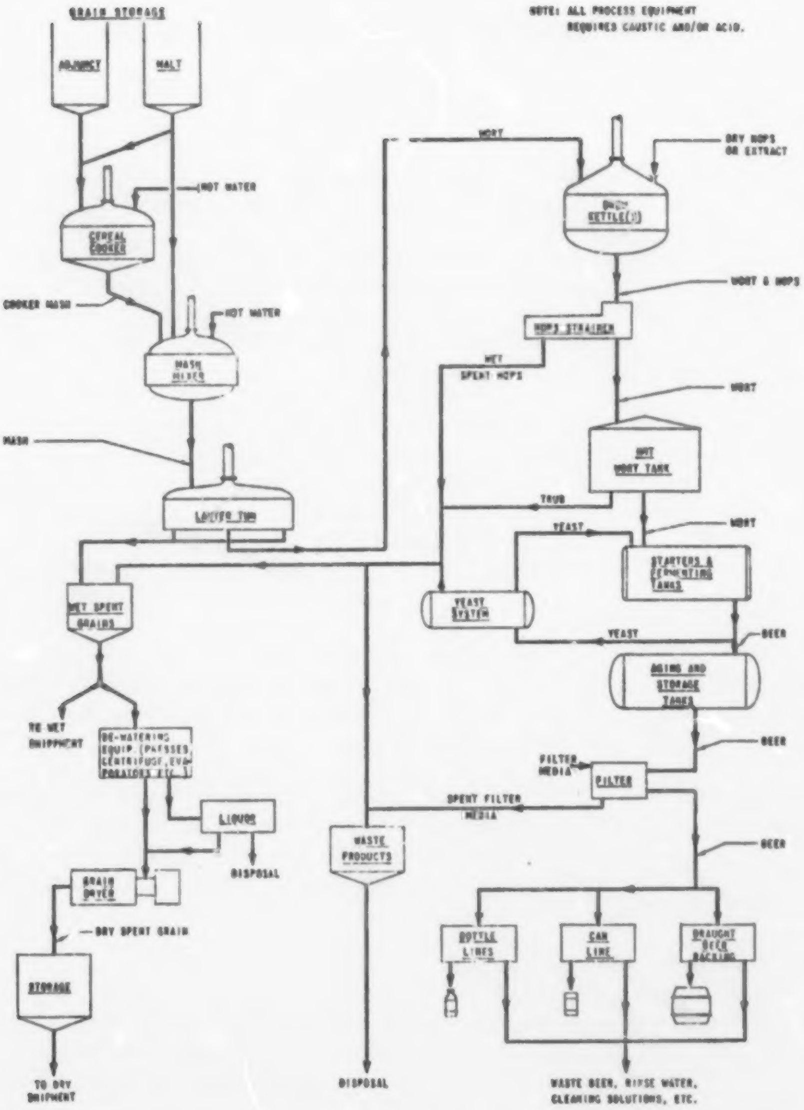
GRAIN STORAGE
ADJUNCT
MALT
HOT WATER
CEREAL COOKER
COOKER MASH
HOT WATER
MASH MIXER
MASH
LAUTER TUB
WET SPENT GRAINS
TO WET SHIPMENT
DE-WATERING EQUIP. (PRESSES, CENTRIFUGE, EVAPORATORS ETC.)
LIQUOR
DISPOSAL
GRAIN DRYER
DRY SPENT GRAIN
STORAGE
TO DRY SHIPMENT
NOTE: ALL PROCESS EQUIPMENT REQUIRES CAUSTIC AND/OR ACID.
WORT
DRY HOPS OR EXTRACT
BREW KETTLE(S)
WORT & HOPS
HOPS STRAINER
WET SPENT HOPS
WORT
HOT WORT TANK
TRUB
YEAST
WORT
STARTERS & FERMENTING TANKS
YEAST SYSTEM
YEAST
BEER
AGING AND STORAGE TANKS
BEER
FILTER MEDIA
FILTER
SPENT FILTER MEDIA
WASTE PRODUCTS
BEER
BOTTLE LINES
CAN LINE
DRAUGHT BEER RACKING
DISPOSAL
WASTE BEER, RINSE WATER, CLEANING SOLUTIONS, ETC.

FIGURE 1 BASIC BREWERY
FLOW DIAGRAM

Beer has a BOD of about 100,000 to 150,000 mg/l and, thus, one 12-oz bottle of beer has just a little less BOD than the daily per capita domestic waste load. Wash-water from the various brewing vessels, general plant washdown, and waste beer from breakage and spillage in the packaging lines, therefore, contribute large waste loads.

Perhaps the largest single waste source is press liquor from grain drying. Spent grain from the lauter tun is normally sold as feed. Rather than sell the wet grain slurry, some brewers elect to partially dry the spent grain using large mechanical presses. The liquor from these presses has a very high BOD content and may constitute 25 percent or more of the total plant BOD load.

The effluent characteristics from ten breweries are given in Table 1. The data presented in this table were collected during plant visits, supplemented by limited information in the literature (2) (3) (4), and demonstrate the high BOD and suspended solids levels in brewery wastes. Those breweries with relatively low BOD levels generally do not press the spent grains, although the concentration depends also on water usage. Water consumption in the industry ranges from 5 to 15 bbl/bbl of beer.

Individual waste parameters fluctuate considerably over the brewing day because of the batch type of operation. Wide variations in pH result from the use of sulfuric acid, sodium hydroxide, and other cleaning compounds. Measurements taken at Brewery A, Figure 2, show changes of 10 pH units within a 30-minute period. A pH of about 4.0 was observed for a three-hour period while the 24-hour composite had a pH of about 6.0.

Other data gathered at Brewery A, see Table 2, indicated a COD:BOD ratio of about 2:1, but this factor was somewhat variable. Soluble BOD constituted about 75 percent of the total BOD. Dissolved solids concentrations averaged 1520 mg/l with peak values up to 2190 mg/l.

PRESENT WASTE TREATMENT PRACTICES

The current state-of-the-art in brewery waste treatment is much less advanced than might be anticipated. Most breweries discharge their wastes into large municipal sewerage systems in which the specific effects of the greatly diluted brewery wastes are difficult to ascertain. At least nine treatment plants throughout the country are presently known to receive a substantial proportion of brewery wastes in their total flow. For purposes of this discussion, a substantial proportion is defined as ten percent or more by volume. Four of the nine plants currently receive only brewery wastes.

During the course of these studies, each of the nine plants was visited at least once. A brief description of the nine treatment facilities is presented in Table 3. All of them have experienced varying degrees of difficulties in treating the brewery discharges.

TABLE 1

BREWERY EFFLUENT CHARACTERISTICS

Brewery	Total Flow mgd	Average BOD mg/1	Peak BOD mg/1	Average Suspended Solids mg/1	pH
A	2.7	1000-1400	2700	500-700	3-12
B	3.4	900	-	500	3-14
C	1.2	850	4800	-	2-12
D	0.35	2000-2300	-	800-1400	-
E	0.85	2800-2900	5000	700-1600	-
F	3.2	1500-2200	5000	200-400	-
G	1.5	6000-8000	11,000	2600-2700	-
H	1.0	2100-4300*	19,000*	-	-
I	5.6**	1000**	-	450**	2-12
J	1.6	980	-	365	-

*COD
**Design values

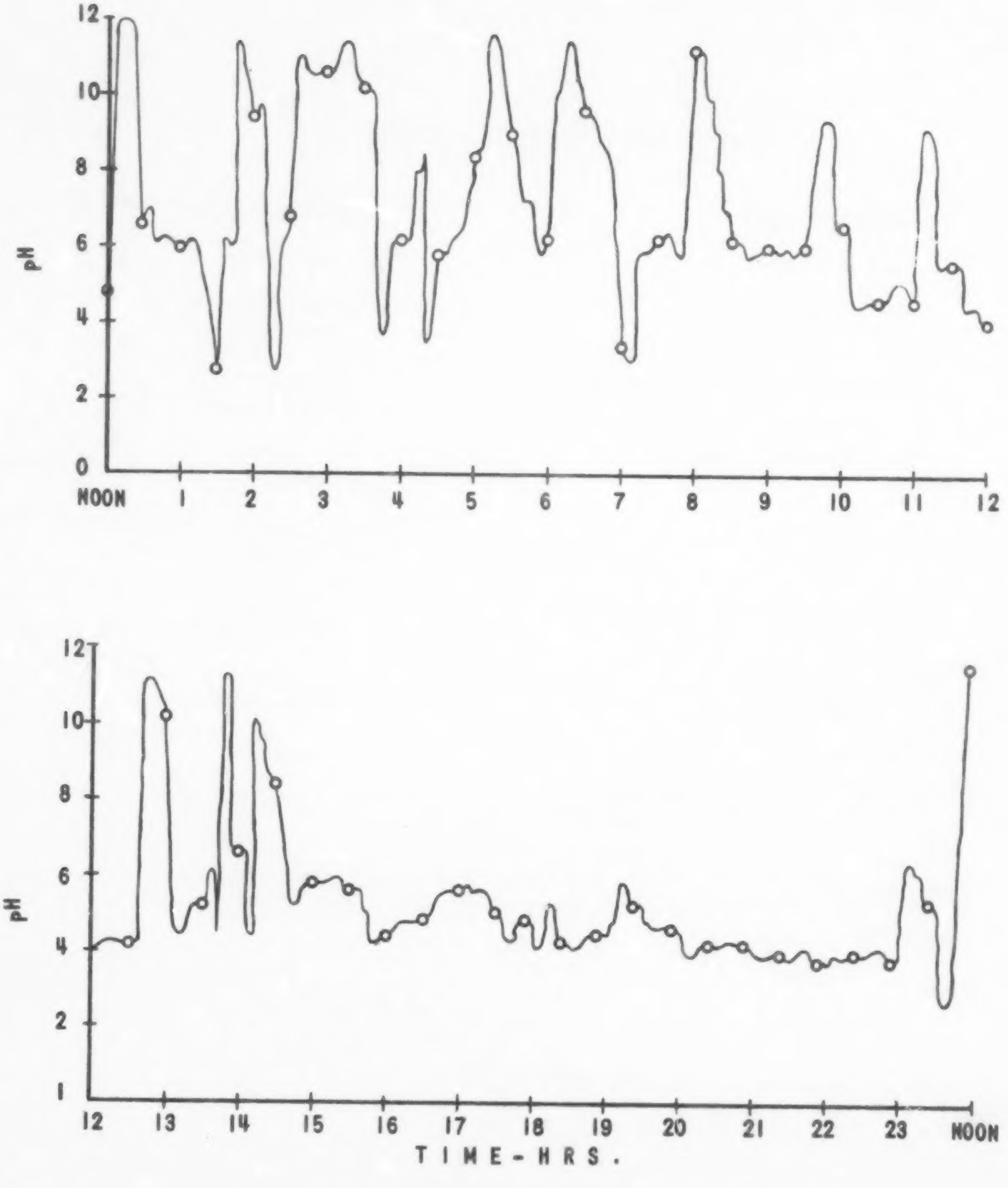

FIGURE 2 pH FLUCTUATIONS OF RAW BREWERY WASTE

TABLE 2

WASTE CHARACTERISTICS - BREWERY A

Characteristic	Operating Data*
Flow - average	2.65 mgd
BOD - average	1000-1400 mg/1
range	400-2700 mg/1
Suspended solids - average	500-700 mg/1
range	140-1340 mg/1
Temperature - average	94°F
range	88-102°F
pH - average	5.5-6.2
range	3-12
**Dissolved solids - average	1520 mg/1
range	770-2190 mg/1
**COD - average	2290
range	560-3800
**COD:BOD ratio	2.0:1
**Soluble BOD:Total BOD ratio	0.75:1

*Based on six-month operating record except as otherwise noted

**Results of eight-day sampling program during plant evaluation study

TABLE 3

WASTE TREATMENT PLANTS HANDLING BREWERY WASTES

Treatment Plant (Brewery)	Waste Treatment Sequence	Sludge Disposal Sequence	Total Flow, mgd	Brewery Flow, mgd	Approximate Treatment Efficiencies, percent	
					BOD	Suspended Solids
A	Clarifier roughing filter, activated sludge (contact stabilization), clarifier, chlorination	Aerobic digestion sludge lagoon	2.65	2.65	80-85	30-70
B	Grit chamber, clarifier, activated sludge (Kraus process), clarifier, chlorination	Storage, flotation, vacuum filtration, land disposal	4.6	3.4	90	85-90
C	Settling basin, activated sludge (Kraus process), settling basin	Anaerobic digestion, drying beds, land disposal	6.65	1.2	94	92
D	Grit chamber, settling basin, activated sludge (Kraus process), settling basin, chlorination	Flotation, anaerobic digestion sludge lagoon	0.70	0.35	90	-

TABLE 3 cont

WASTE TREATMENT PLANTS HANDLING BREWERY WASTES

Treatment Plant (Brewery)	Waste Treatment Sequence	Sludge Disposal Sequence	Total Flow, mgd	Brewery Flow, mgd	Approximate Treatment Efficiencies, percent	
					BOD	Suspended Solids
E	Pretreatment (brewery wastes) equalization basin, clarifier, roughing filter, clarifier, trickling filters, clarifier, lagoons	Thickener anaerobic digestion drying beds, land disposal	8.5	0.85	60-70	35-60
F	Equalization basins, clarifier, roughing filter, activated sludge (conventional), clarifiers, chlorination	Flotation, thickeners, vacuum filters, land disposal	3.2	3.2	-	-
G	Clarifiers, trickling filters, activated sludge, settling basins	Anaerobic digestion drying beds, kiln drying, sale as fertilizer	20	1.5	-	-

TABLE 3 cont

WASTE TREATMENT PLANTS HANDLING BREWERY WASTES

Treatment Plant (Brewery)	Waste Treatment Sequence	Sludge Disposal Sequence	Total Flow, mgd	Brewery Flow, mgd	Approximate Treatment Efficiencies, percent	
					BOD	Suspended Solids
H	Grit chamber, clarifiers, roughing filters, activated sludge (contact stabilization), clarifiers, lagoon	Aerobic digestion, sludge lagoons, spray irrigation	1.0	1.0	95	95
I	Clarifiers, activated sludge (complete mix), clarifiers, chlorination	Thickeners, spray irrigation	9.6*	5.6*	90+	-

*Design values

Activated Sludge Systems

Eight of the nine treatment plants use some form of the activated sludge process. The Kraus process or a modification thereof is used at three older installations, B, C, and D. Interestingly, these three systems were all originally designed and/or operated as conventional activated sludge systems and were later converted to the Kraus process. In each case, sludge bulking became a major problem when the conventional system was used. The Kraus process has been the only successful means of controlling bulking at these plants. Chlorination of the return sludge for control of filamentous organisms was tried at one location without success. As used at Plants B, C, and D, the Kraus process has generally proved to be an effective method for treating brewery wastes. It should be noted, however, that these three systems also receive municipal wastes.

The only complete-mix activated sludge system, Plant I, has been in service only a few months and operating data are unavailable. Presently, the treatment plant receives only brewery wastes although municipal wastes will soon be added. Because of the low flows, the detention time in the force main is about six hours and the waste is septic when it arrives at the treatment facility. The resulting odors are very prevalent near the primary clarifiers.

The complete-mix system at Plant I was designed for a food:microorganisms ratio of less than 0.4 lb of BOD removed/lbs mixed liquor suspended solids. A chlorination system for the return sludge has been provided to control sludge bulking should it occur. To date, no such problems have arisen; however, the true test will not occur until the system approaches design loadings.

On three occasions, acid conditions in the influent waste stream, i.e., pH values below 4.0, have killed the activated sludge system. Such discharges are now being neutralized at the brewery. The thickener apparently has very little effect on the waste activated sludge. BOD levels in the effluent are reported to be below 25 mg/1, but the secondary clarifier overflow has a noticeable suspended solids content.

A conventional plug-flow activated sludge system is used at Plant F, which has been in operation for about two years. In spite of equalization basins, nutrient addition, and a roughing filter ahead of the activated sludge system, severe sludge bulking has occurred as it has at many brewery waste treatment plants. Anaerobic conditions, causing rising sludge, clearly exist in the primary clarifiers, and the combined primary and waste activated sludges cannot be thickened in the conventional gravity unit. Fortunately, the flexibility and large capacity of the treatment system will enable some of these problems to be solved by operational changes.

Plants A and H employ contact stabilization following roughing filters. The contact stabilization process is particularly suitable for wastes with high proportions of suspended and colloidal BOD, but its application to the highly soluble BOD waste from breweries warrants examination.

The overall treatment efficiencies at Plant A have been below expectations, with BOD removals of about 80 percent and suspended solids reductions in the 30 to 70 percent range. Studies at the plant show an effective loading rate of 0.78 lb BOD/lb MLSS based on contact and reaeration tank volumes. Sludge bulking is a periodic problem at this very high loading rate, as evidenced by poor suspended solids removals. Modifications are presently being made to this treatment system in accordance with the results of pilot plant studies to be discussed in a subsequent section.

Plant H is very similar to Plant A in the basic process sequence, but the results at Plant H are markedly superior. This facility has been in operation about 1½ years, with treatment efficiencies well above 90 percent. The excellent performance can be attributed to several factors, not the least of which is the in-house control exercised by the brewery. Press liquor is pumped to a holding tank and fed to the treatment plant at a constant rate seven days a week. Similar controls are practiced for spent caustic solutions.

A second factor contributing to the performance is a ten-acre polishing lagoon with a 15-day minimum detention time. The lagoon follows the main treatment operation and serves as added insurance against plant upsets. In fact, it was observed that the effluent from the secondary clarifiers contained appreciable suspended solids which were later removed in the lagoon.

The final major factor influencing the plant performance is the fact that the present loading on the plant appears to be well below design levels. The design was based on a BOD:MLSS ratio of 0.38.

Trickling Filter Systems

Conventional trickling filters for complete secondary treatment have been used in the past at Plants D, E, and G. The trickling filter at Plant D was abandoned in favor of the present Kraus system after several years of difficulty. Plant E currently uses two large filters in series to handle the combined domestic and pretreated brewery wastes. The overall treatment efficiencies are 60 to 70 percent for BOD and 35 to 60 percent for suspended solids. Plant G recently upgraded its trickling filter system by adding activated sludge in series to the treatment sequence and by covering the filters with styrofoam domes to contain odors. Undoubtedly, the extensive modifications to Plant G have significantly improved treatment performance, but data on the new system are not available. The performance of trickling filter installations handling brewery wastes has been mediocre at best. Treatment efficiencies have been well below current acceptable levels and offensive odors have compounded the problems.

Plastic media trickling filters are used as roughing units at four locations, Plants A, E, F, and H. The purpose of these roughing filters, designed to remove 45 to 60 percent of the BOD, is to reduce the high-strength of the influent brewery wastes to more manageable levels.

Generally, the roughing filters seem to have met the design criteria, but not without some problems. With the exception of Plant H, the filters all generate objectionable odors, at times discernible for several miles. The septic nature of the waste as it leaves the primary clarifier and the anaerobic conditions in the roughing filter result in significant odor generation. Measurements at two of these plants showed zero dissolved oxygen in the wastes throughout the roughing filters. Little or no odor can be detected from the roughing filters at Plant H, possibly a reflection of lower loading rates at present.

Sludge Disposal

The disposal of primary and secondary sludges from brewery waste treatment operation is a severe problem, as it is at many treatment plants. The high BOD and suspended solids content of brewery wastes, however, results in a much higher solids production per unit volume of waste than many other wastes. A variety of sludge disposal methods have been used for brewery wastes with mixed results.

Gravity thickening has been used with little success on both combined and waste activated sludges. Three plants presently use dissolved air flotation for thickening waste activated sludge with similar results, specifically a discharge solids content of about three to four percent.

Plants C, D, E, and G, use anaerobic digestion as their main sludge disposal method. The digestion systems perform quite satisfactorily in terms of volatile solids reductions, but little solids separation is achieved in the second stage digesters. Three of the four plants use sludge drying beds, while the digester liquor from Plant D is discharged to a sludge lagoon which creates odor problems, particularly in the spring. Notably, the percentage of brewery wastes and, hence, brewery sludge is much higher at Plant D than at the other plants using anaerobic digestion.

Aerobic digestion is used at Plants A and H, but is soon to be replaced with incineration at the former. Insufficient digestion capacity at Plant A resulted in only partial digestion and stabilization. Both plants initially discharged the digested solids to sludge lagoons, but severe odor problems eventually forced an end to this practice. The application of lime, masking agents, and other chemical controls failed to eliminate or even markedly improve the situation.

Plant H is now experimenting with spray irrigation for disposing of the digested sludge. Spray irrigation is also used at Plant I, but without digestion.

Plants B and F use vacuum filters and dispose of the filter cake in landfills. A thermal sludge-conditioning unit was installed about two years ago at Plant B to reduce or eliminate the high operating cost of chemical conditioning. At the same time, the heat-treatment decant liquor was substituted for digester liquor in the Kraus process. The high strength, resolubilized BOD in the decant liquor apparently overloaded the activated sludge system and caused a precipitous drop in the overall plant efficiency. Moreover, the heat treatment process generated very objectionable odors. Within six months, the carbon steel heat exchanger failed as a result of corrosion and the system was abandoned. Interestingly, while the system was in service it yielded a filter cake with about 40 percent solids with no chemical conditioners. This result is to be compared with a 15 percent solids content in chemically conditioned filter cake using 15 to 20 percent lime and 7 to 9 percent ferric chloride at the same plant.

PILOT PLANT STUDIES

Since system start-up in 1969, Plant A has experienced a series of operational difficulties, some of which have been discussed previously. A flow diagram of the treatment system, previously described in Table 3, is shown in Figure 3. The treatment plant receives only brewery wastes at present, although domestic wastes will be added in the near future at about a 1:1 ratio.

One of the major concerns at Plant A has been the inability of the system to consistently achieve satisfactory treatment levels. Extensive field studies of the existing system indicated that the contact stabilization process was poorly suited to the high soluble-BOD nature of the brewery wastes, especially at the very high loading rates experienced, i.e., 0.78 lb BOD/lb MLSS.

As a result of these problems, a series of pilot plant studies were undertaken to evaluate the treatability of the waste using the complete-mix activated sludge process. Studies were conducted with raw brewery wastes, trickling filter effluent, and a mixture of domestic and brewery wastes. In addition, a brief experiment was run on aerobic sludge digestion. Results from the pilot plant studies are presented in the following sections.

Experimental Facilities

The field studies conducted at the Plant A site were in two pilot units. Pilot Plant No. 1 consisted of a 650 gal, 18.0 ft^2 surface area primary clarifier; a 1,970 gal aeration tank; and a 512 gal, 16.0 ft^2 surface area secondary clarifier. Pilot Plant No. 2 consisted of a 140 gal, 6.0 ft^2 surface area primary clarifier; a 419 gal aeration tank; and a 140 gal, 6.0 ft^2 surface area secondary clarifier. Air for the aeration tanks and sludge return lines was provided by individual compressors for each unit.

Samples were composited by automatic sampling devices where feasible and most chemical analyses were conducted on site in a mobile laboratory. All tests were conducted in accordance with Standard Methods for the Examination of Water and Wastewater, 12th Ed., with the exception of dissolved oxygen, which was measured by a dissolved oxygen probe calibrated against the standard Winkler titration.

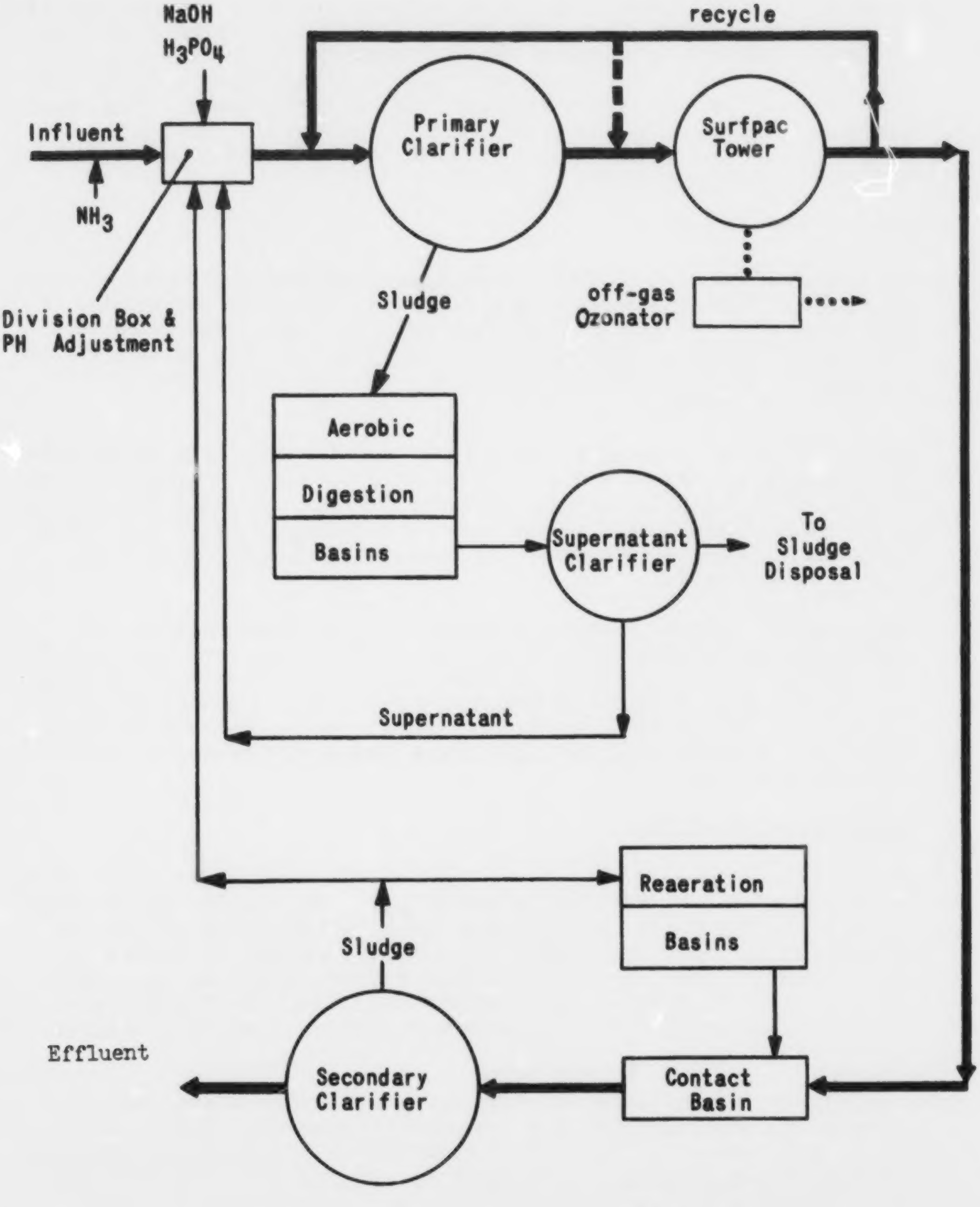
NaOH
H_3PO_4
recycle
Influent
NH_3
Primary Clarifier
Surfpac Tower
Division Box & PH Adjustment
Sludge
off-gas Ozonator
Aerobic
Digestion
Basins
Supernatant Clarifier
To Sludge Disposal
Supernatant
Reaeration
Basins
Sludge
Effluent
Secondary Clarifier
Contact Basin

FIGURE 3 WASTE TREATMENT FLOW DIAGRAM FOR BREWERY A

Treatment of Raw Brewery Waste

Pilot Plant No. 1 was used for the experiments on the treatment of raw brewery waste. The unit was placed into operation by filling the aeration tank with settled brewery waste and seeding with 600 gallons of return activated sludge from Plant A. The activated sludge system was acclimated stepwise over a 17-day period to an hydraulic feed rate of 1500 gal/day, which gave an average loading rate of 0.21 lb BOD/lb MLSS. Ammonium nitrate was added to supplement the low level of nitrogen, about 1 - 6 mg/l as N, in the influent waste.

After the system was stabilized, 24-hour composite samples were analyzed over an eight-day period. Subsequently, the average loading rate was increased to 0.56 lb BOD/lb MLSS and samples were collected and analyzed for an additional 12-day period. The data gathered during these experiments are summarized in Table 4 for runs A1 and A2 and are presented graphically in Figures 4 and 5.

The results of these pilot plant studies indicate that raw brewery waste can be easily biodegraded by the complete-mix activated sludge process. At the lower loading rate of 0.21 lb BOD/lb MLSS, the soluble BOD in the effluent was always less than 20 mg/l and averaged 8.0 mg/l. At the higher rate of 0.56 lb BOD/lb MLSS, the effluent soluble BOD averaged 14 mg/l.

The soluble BOD removal rate, K_2, was calculated based on the equations (5):

$$\frac{Lo - Le}{Le} = K_2 S_a t$$

$$K_2 = K_2^{20^\circ} \theta^{(T-20)}$$

where:

K_2 = removal rate constant
Lo = influent soluble BOD
Le = effluent soluble BOD
Sa = mixed liquor suspended solids
t = time under aeration, detention time
θ = 1.056 (20° to 30°C)
θ = 1.135 (4° to 20°C)

Average values calculated for the several runs are given in Table 5.

In view of past experience with sludge bulking, one of the major items of interest in these studies was the sludge volume index (SVI). The SVI averaged 230 for the lower organic loading rate and 346 at the higher rate. A sludge with an SVI of 230 can be settled in a conservatively designed secondary clarifier, but it is difficult to achieve adequate liquid-solid separation consistently with an SVI of 346.

TABLE 4

SUMMARY OF PILOT PLANT RESULTS

Pilot Plant Run	Feed Type	BOD Loading lb BOD/lb MLSS		Sampling Point*	Constituent Averages			
					Total Suspended Solids	BOD		COD
		Total	Soluble		mg/l	Total mg/l	Soluble mg/l	Total mg/l
A1	Brewery waste-Primary effluent	0.21	0.14	Influent	262	1,151	812	2,350
				Effluent	25	10	8	77
A2	Brewery waste-Primary effluent	0.56	0.39	Influent	415	1,260	974	2,062
				Effluent	136	38	14	189
A3	Brewery waste-T. F. effluent	0.18	0.13	Influent	192	403	294	797
				Effluent	22	18	6	75
A4	Brewery waste-T. F. effluent	0.54	0.34	Influent	346	451	304	889
				Effluent	190	83	33	267
A5	Brewery waste-T. F. effluent plus settled domestic sewage 1:1	0.32	-	Influent	209	432	-	734
				Effluent	37	35	10	113

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*Influent to activated sludge tank and effluent from secondary clarifier.

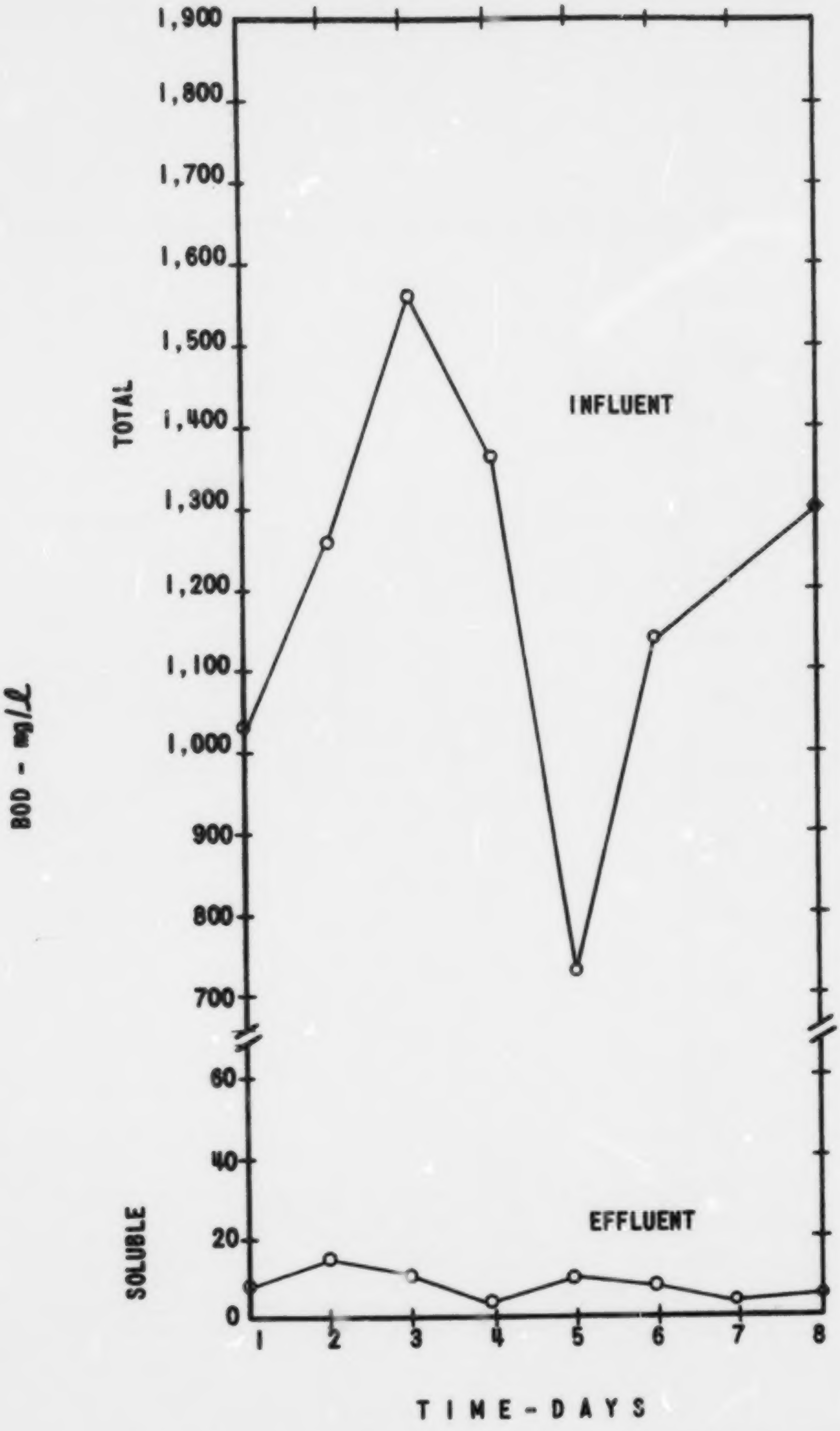

FIGURE 4 BOD REDUCTION IN PILOT PLANT TREATING SETTLED BREWERY WASTE. AVERAGE LOADING RATE - 0.21 lb BOD/lb MLSS/day

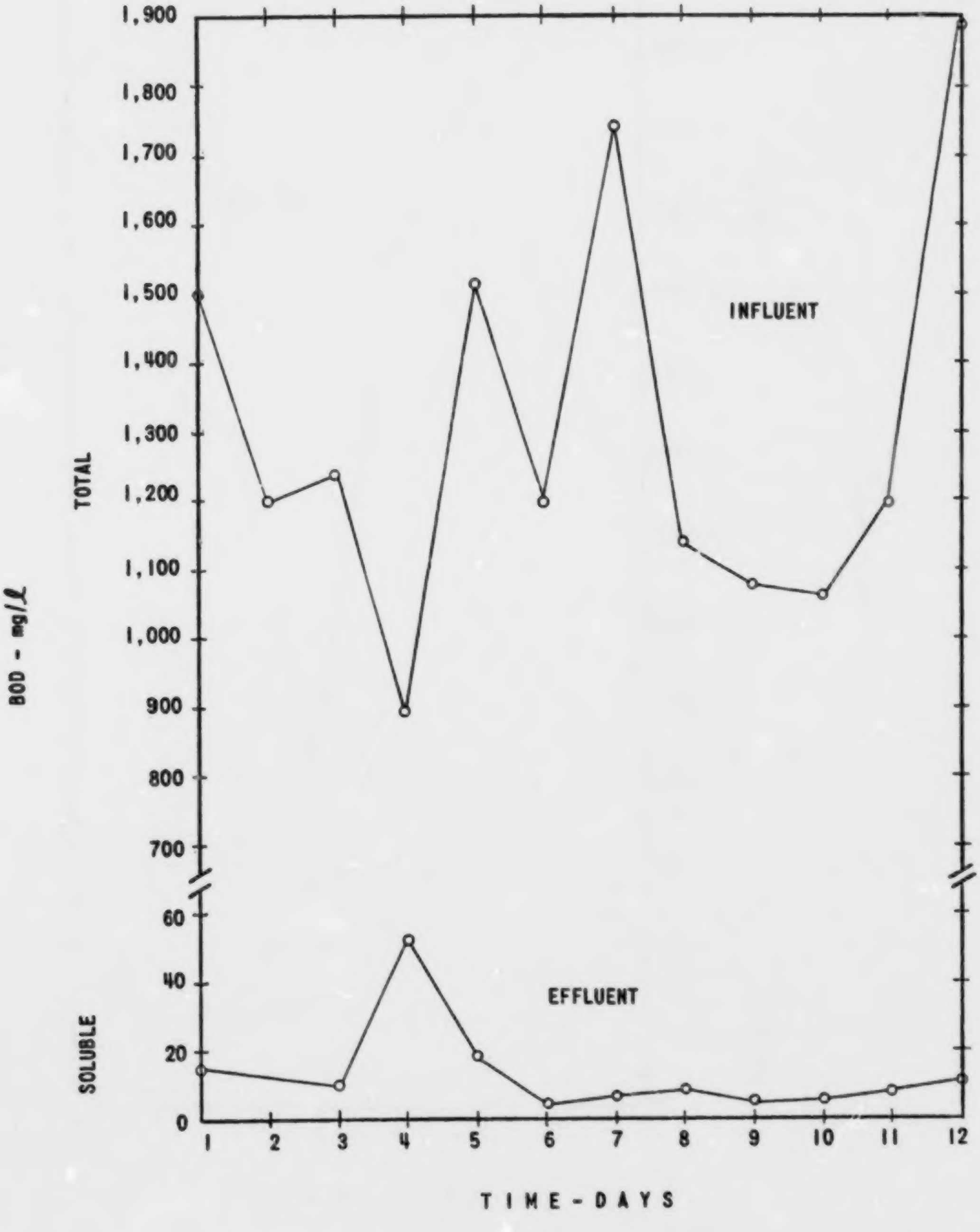

FIGURE 5 BOD REDUCTION IN PILOT PLANT TREATING SETTLED BREWERY WASTE. AVERAGE LOADING RATE - 0.56 lb BOD/lb MLSS/day

TABLE 5

SOLUBLE BOD REMOVAL RATE CONSTANTS

Pilot Plant Run	Lo, mg/1	Le, mg/1	Sa, mg/1	t, days	Lo/Sat, 1b BOD/1b MLSS	K_2, 1/gm-hr	T, °C	K_2, 20° 1/gm-hr
A1	812	8	3870	1.51	0.14	0.92	18	0.96
A2	974	14	2770	0.95	0.39	2.07	20	2.25
A3	294	6	4030	0.60	0.13	1.44	19	1.70
A4	304	33	2510	0.36	0.34	0.58	22	0.59

Treatment of Trickling Filter Effluent

The experiments on treatment of trickling filter effluent were conducted in Pilot Plant No. 2, which was operated concurrently with Pilot Plant No. 1. The system was placed in operation by filling the aeration tank with filter effluent and 100 gallons of return activated sludge seed. The trickling filter effluent was fed directly into the aeration tank at a rate that was increased to 700 gpd by the end of the acclimation period. This rate gave an average loading of 0.18 lb BOD/lb MLSS. Composite samples were collected and analyzed over an eight-day period. The average loading rate was then increased to 0.54 lb BOD/lb MLSS. After the system stabilized at the higher loading rate, composite samles were collected for 13 additional days.

Results of the test runs A3 and A4 are also given in Table 4 and shown in Figures 6 and 7. At the lower loading rate, the treatment efficiency was excellent with an average effluent total BOD of 18 mg/1. The soluble BOD was always below 15 mg/1 and averaged 6.0 mg/1. When the loading was increased to 0.54 lb BOD/lb MLSS, the effluent quality decreased markedly with an average soluble BOD of 33 mg/1 and a total BOD of 83 mg/1. Removal rate constants for the soluble BOD were calculated and are shown in Table 5.

The SVI at the 0.18 lb BOD/lb MLSS loading rate fairly consistently averaged 215. At the higher loading rate, however, the SVI varied widely from 92 to 317. Once again, the data indicated increased difficulty in settling at the higher loading rates.

Treatment of Combined Wastes

Pilot Plant No. 2 was used for the experiments with a 1:1 mixture of trickling filter effluent and settled domestic sewage. Following the studies on trickling filter effluent, settled sewage was added to the influent waste stream. The feed rate of each waste was set at 650 gpd to produce a detention time of 7.7 hours and a loading rate of 0.32 lb BOD/lb MLSS. Composite samples of the two influent streams and the secondary effluent were collected for nine days and the data summarized as run A5 in Table 4 and shown in Figure 8.

During this test run, a styrofoam dome was placed over the roughing filter to control odors, and the effluent BOD increased significantly. The average filter effluent BOD during the pilot plant test was 723 mg/1 with BOD concentrations greater than 1,000 mg/1 on two separate days. The average total BOD in the pilot plant effluent was 35 mg/1, giving a total BOD removal efficiency of approximately 92 percent. The soluble BOD in the effluent remained below 10 mg/1, with the exception of the last two days of operation when the filter effluent BOD increased to over 1,000 mg/1. The results of this study indicated that a mixture of settled sewage and brewery waste can be effectively treated by the complete-mix process.

Of special note, the SVI during this experiment averaged 183, which is considerably below the values recorded for brewery wastes alone. This

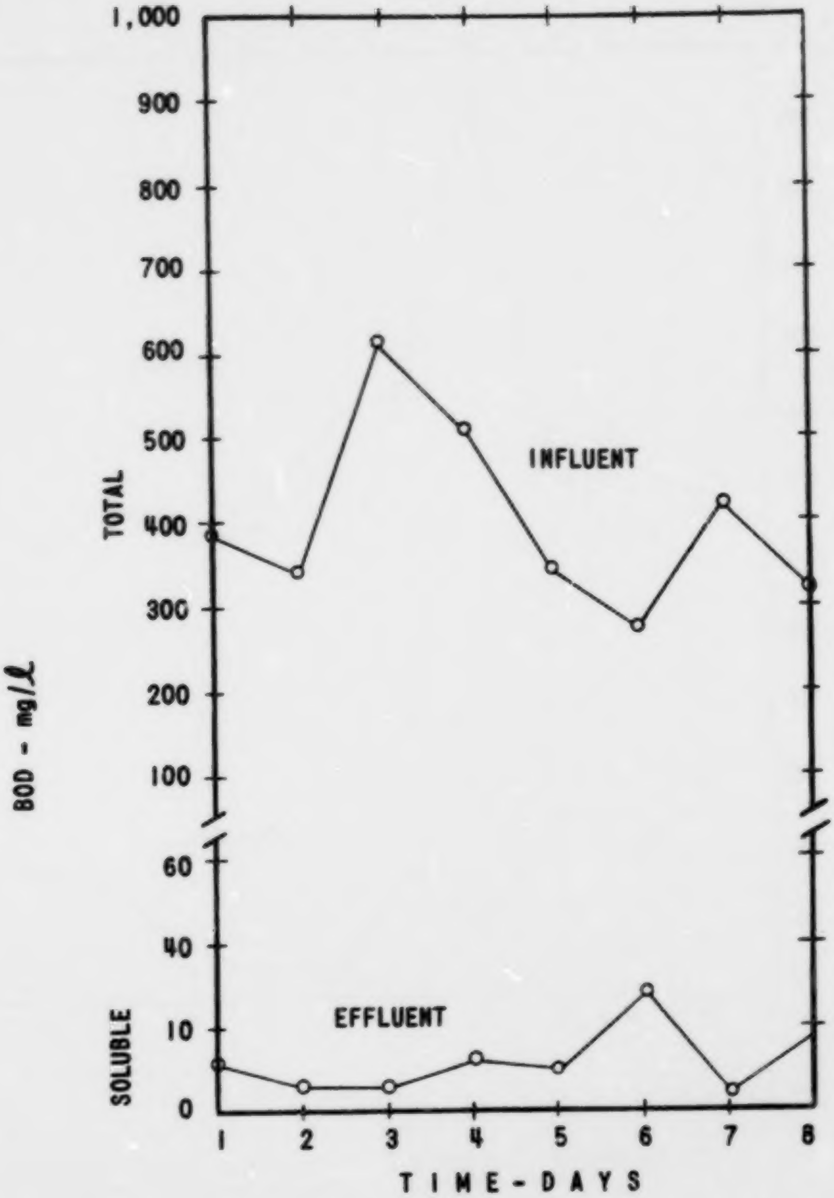

FIGURE 6 BOD REDUCTION IN PILOT PLANT TREATING TRICKLING FILTER EFFLUENT. LOADING RATE - 0.18 lb/BOD/lb MLSS/day

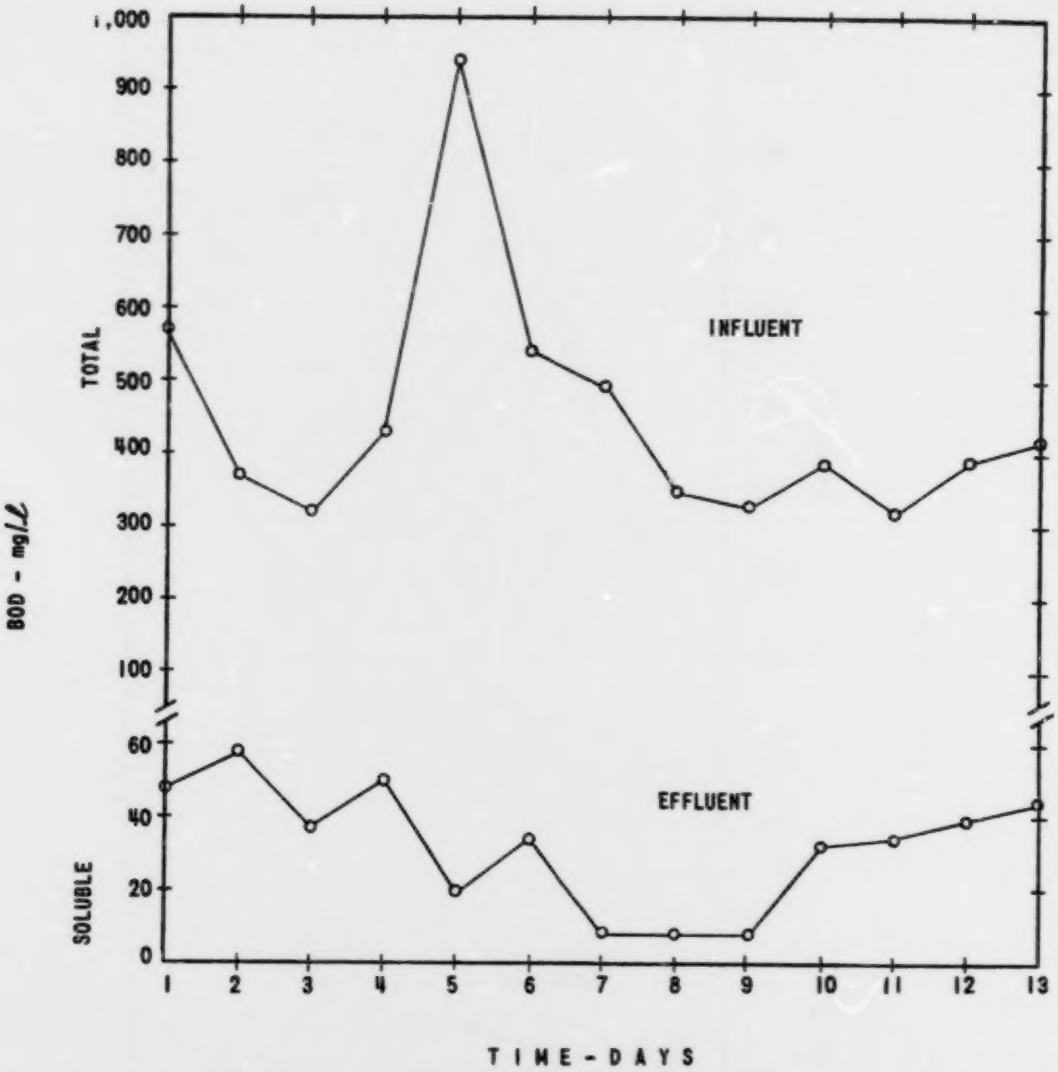

FIGURE 7 BOD REDUCTION IN PILOT PLANT TREATING TRICKLING FILTER EFFLUENT. LOADING RATE - 0.54 lb BOD/lb MLSS/day

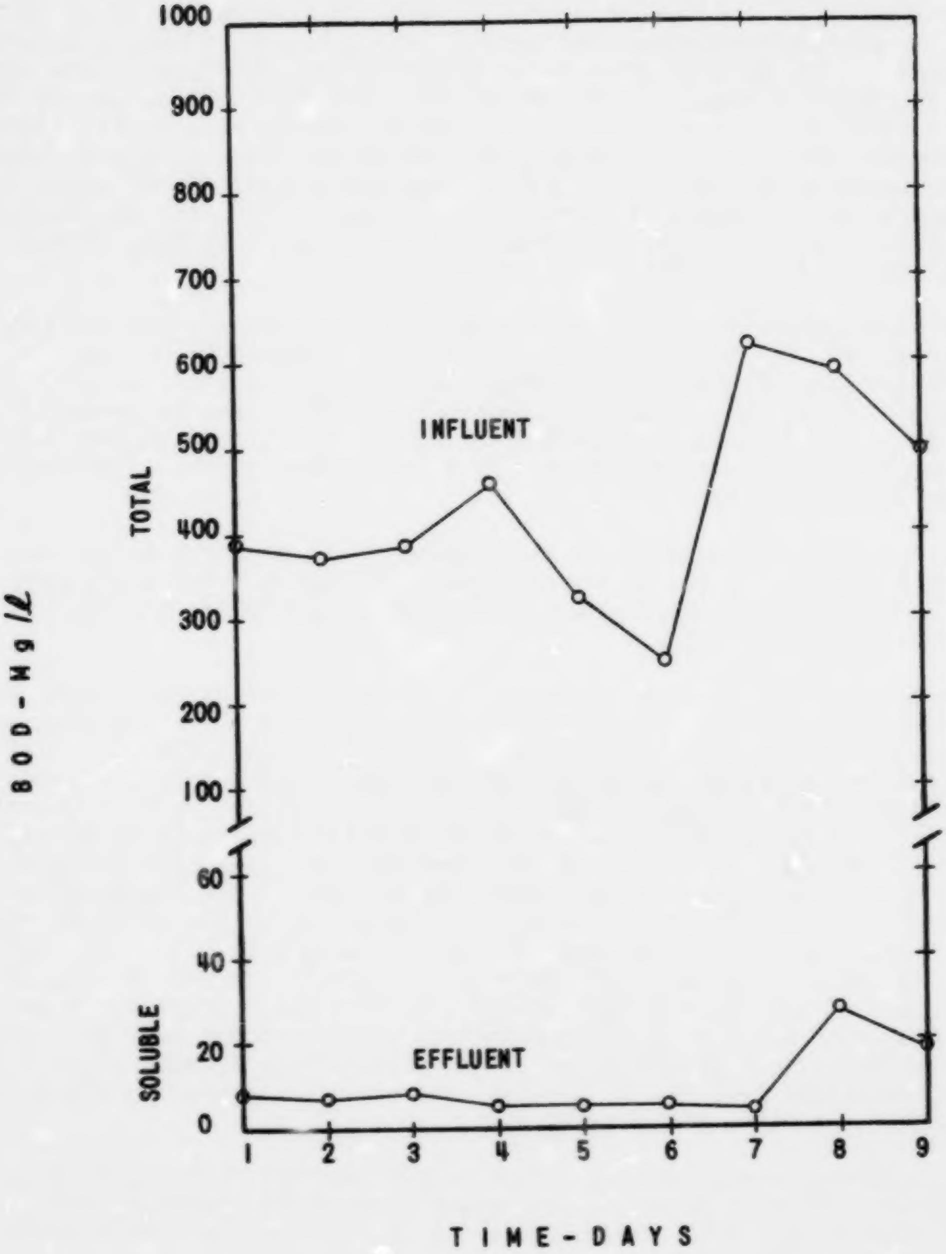

FIGURE 8 BOD REDUCTION IN PILOT PLANT TREATING 1:1 RATIO SETTLED SEWAGE AND FILTER EFFLUENT LOADING RATE - 0.32 lb BOD/lb MLSS/day

result indicates improved settleability for the combined wastes, perhaps a significant factor in achieving good plant performance.

Aerobic Digestion of Sludge

The first test conducted on aerobic sludge digestion was in Pilot Plant No. 1 on a semicontinuous feed basis. Initially, 30 gallons of primary sludge and 150 gallons of waste activated sludge from Plant A were added to the aeration basin. Every second day thereafter, 180 gallons of feed were added to the tank with a corresponding removal of effluent. This procedure resulted in a suspended solids concentration of approximately 1.0 percent with a 22-day hydraulic retention period. In an effort to concentrate the sludge by raising the average influent BOD and suspended solids, the feed rate was changed to 70 gallons of primary sludge and 120 gallons of waste activated sludge.

The volatile solids loading on the aerobic digester averaged 0.075 lb/ft^3/day over the testing period. Reductions achieved by the aerobic digester were 36 percent in volatile solids and 40 percent in BOD. A summary of the pilot plant performance during this test is presented in Table 6. The data show performance comparable with published values on aerobic digesters and indicate that this sludge may be successfully treated aerobically.

A brief test was conducted on the digester effluent for possible odor problems by drying six inches of digested sludge on a makeshift sandy earth bed. The sludge dewatered very rapidly and left a dry residue with no noticeable odor.

Researchers have recently attempted to correlate the degree of sludge digestion with changes in sludge parameters such as pH, alkalinity, and nitrate content. A batch study was initiated in Pilot Plant No. 2 with 70 gallons of primary sludge and 120 gallons of waste activated sludge. Analyses were conducted on this sample during aeration to determine the parameters against which the degree of sludge digestion could be measured. The data obtained from the experiment are presented in Figure 9. It may be seen that for this single sludge sample, essentially all of the BOD and volatile solids removal was completed by the sixteenth day of operation. Correspondingly, the pH had dropped to 5.0 by the eighteenth day of operation, and the total alkalinity was reduced from over 300 mg/l to less than 50 mg/l by the sixteenth day. Comparing these results with alkalinity and pH data from the continuous feed test reveals that with a pH of 5.0 to 6.0 and alkalinities around 40 mg/l, the continuous feed process accomplished essentially complete digestion within a retention period of 21 days.

The indicated changes are explained by the fact that aerating a carbonate-bicarbonate water removes carbon dioxide and gradually lowers the alkalinity. While the sludge is still actively digesting, carbon dioxide is being returned to the water. A sharp drop in alkalinity, therefore, does not occur until digestion is substantially slowed. Furthermore, with the drop in buffering capacity of the liquid and the conversion of organic and ammonium nitrogen to the nitrate form, acidity increases and the pH drops to some new low level.

TABLE 6

AEROBIC SLUDGE DIGESTER PERFORMANCE

CONTINUOUS FEED**

Constituent Averages

	COD-mg/1	BOD-mg/1	Solids-mg/1					Average DO Uptake
	Total	Total	Total	Suspended	Volatile	pH	Alkalinity	mg/1/hr
Feed	20,193	5,678	14,409	13,262	12,434	-	-	-
Effluent	10,240	3,207	9,754	7,869	7,894	6.1	32	38
% Reduction	49.0	43.5	32.4	40.6	36.7	-	-	-

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*Feed added and effluent withdrawn every two days.

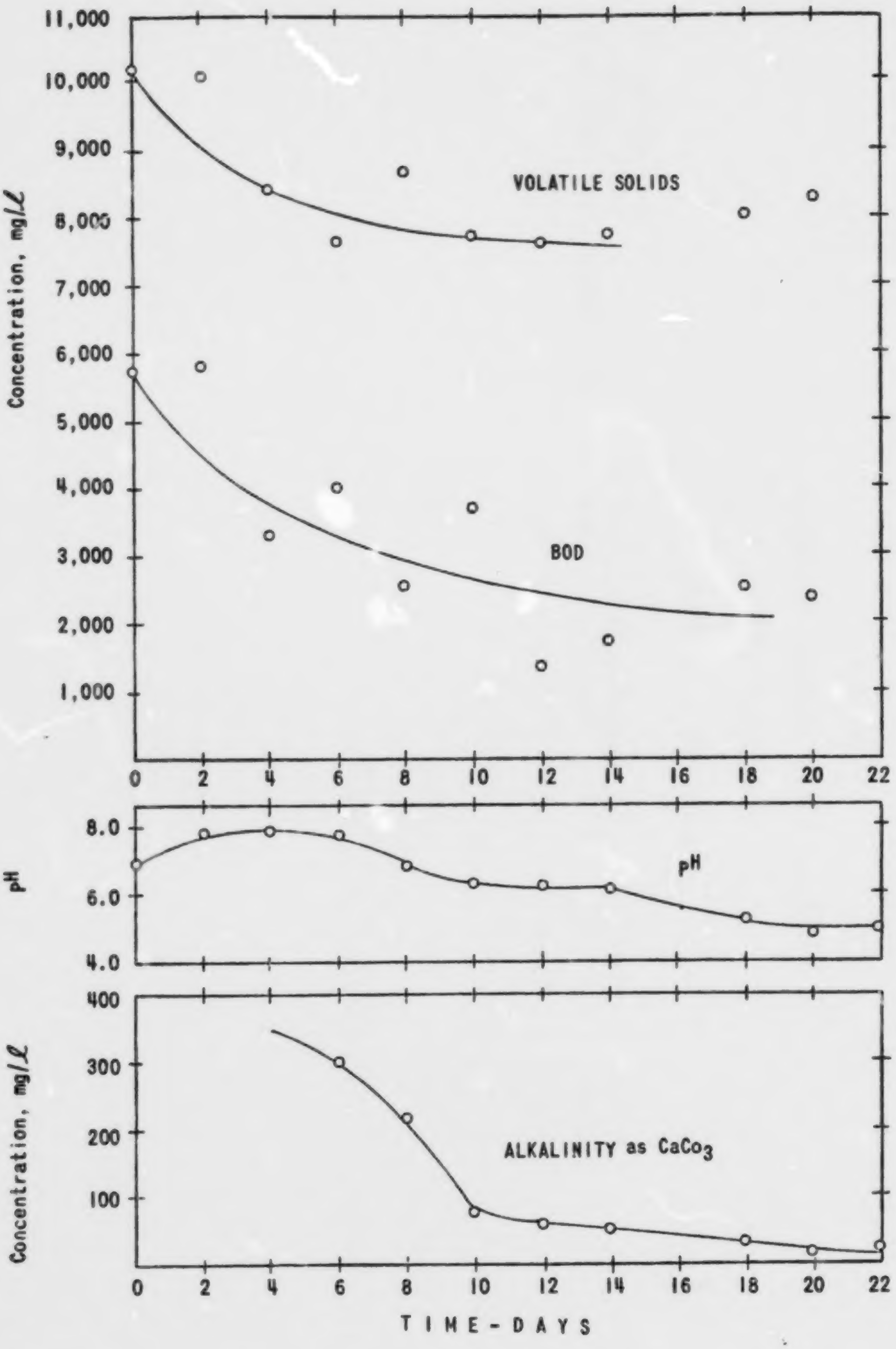

FIGURE 9 BATCH DIGESTION OF BREWERY WASTE SLUDGE

DISCUSSION

Based on the results of these pilot plant studies, design criteria for a complete-mix activated sludge system to handle brewery wastes have been established as follows:

1. Primary clarification, surface loading rate: 750 gpd/ft^2
2. Aeration basin, loading rate: 0.25-0.30 lb BOD/lb MLSS (based on 2,500 mg/l MLSS)
3. Secondary settling, surface loading rate: 400-500 gpd/ft^2

Recommendations have been made and are being implemented to modify Plant A in accordance with the pilot plant studies. The existing aerobic digesters will be converted to activated sludge basins with new sludge incineration facilities for sludge disposal. Because of piping restraints, the initial plant modifications will create an activated sludge system more closely resembling step-feed. Total conversion to a complete-mix pattern may be undertaken at a later date.

A relatively low organic loading rate appears essential if sludge bulking is to be controlled. The addition of domestic wastes appears to improve sludge settleability significantly.

The use of a pure oxygen system may offer special advantages in controlling sludge bulking. With a high strength brewery waste, it is often difficult, if not impossible, to maintain satisfactory dissolved oxygen levels throughout the aeration basin using conventional aeration equipment. At low dissolved oxygen levels, 0.1-0.2 mg/l, Sphaerotilus-type organisms compete very strongly and may give rise to sludge bulking. The use of pure oxygen in place of aeration is suggested as a possible remedy for this situation.

CONCLUSIONS

The treatment of brewery wastes has proved difficult at numerous installations throughout the country. Two major difficulties, high organic loadings and sludge bulking, are repeatedly encountered.

Activated sludge systems seem to offer the best approach for handling the high soluble BOD wastes. Several Kraus modifications of the activated sludge process are functioning reasonably well on brewery wastes without appreciable bulking. Pilot plant studies reported herein indicate that complete-mix activated sludge can perform equally well without bulking if the loading rate is kept relatively low, i.e., about 0.3 lb BOD/lb MLSS.

Plastic-media trickling filters have been used as roughing units at several locations. Although the filters accomplish 45 to 60 percent BOD removals, most of these units have given rise to objectionable odors detectable outside the treatment plant property. Unless the odors can be eliminated, roughing filters appear to have limited application for brewery wastes.

Finally, in-plant control of some of the major waste streams can vastly improve the waste treatment plant operations. In particular, the collection and equalized discharge of press liquor and caustic and acid cleaning solutions will greatly reduce the treatment problems inherent with brewery wastes.

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CATTLE PAUNCH CONTENTS AS FISH FEED SUPPLEMENT: FEASIBILITY STUDIES

by

S. C. Yin and Jack L. Witherow*

SUMMARY

The seriousness of cattle paunch contents from abattoirs as a water pollutant was pointed out. As a remedy, it was suggested that the material be dried and used as a feed supplement in the rapidly growing commercial channel catfish farming industry. Air drying and BOD of fresh paunch were studied, as well as the frequency of occurrence of Salmonellae in the material. An EPA grant project (12060 HVQ) at Oklahoma State University will study the feasibility of using dried paunch as a feed supplement in both pond and cage cultures of channel catfish; the effects of the two methods of culture and the possible deleterious effect of incorporating dried paunch in fish feed on water quality will also be determined.

INTRODUCTION

Among abattoir wastes, the rumen or paunch contents of cattle rank high as water pollutants. This material from the rumen, also known as paunch or paunch manure, is simply the partially digested food which the animal has ingested and stored in the first compartment of the stomach. Technically, therefore, this material cannot be considered as fecal material, and the common name--paunch manure--is a misnomer, although from the standpoint of appearance and odor, manure is indeed an appropriate name for the substance.

High solids and high BOD are the characteristics which make paunch a serious water pollutant. The paunch is handled wet or dry. In wet handling, the contents are washed with large volumes of water. The larger solid particles are usually screened out and disposed of in some manner as solid wastes. However, studies done at the Robert S. Kerr Water Research Center and elsewhere have shown that about 80 percent of the BOD of paunch is water soluble. Thus, in this method of handling, about 80 percent of the BOD of paunch is found in the liquor that passes through the screen, adding a tremendous load to the wastewater. In dry handling, the contents are dumped dry and hauled off for disposal on land. Ideally, the material is spread thinly on cultivated land and then immediately covered with a layer of soil or tilled in with the soil, where the material will slowly decompose, acting as a fertilizer and soil conditioner. In this way, not only is water pollution eliminated, but fly breeding and odor nuisance are also precluded. Unfortunately, this is rarely done. A common practice is to openly dump the material into the nearest gully--a practice which eliminates paunch from the wastewaters of the plant

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*Environmental Protection Agency, Robert S. Kerr Water Research Center, P. O. Box 1198, Ada, Oklahoma 74820.

and superficially appears to have taken care of this potential pollutant; for, not only are these open dumps breeding sanctuaries for flies, but any rainfall runoff will carry a substantial portion of the material into the nearest water course.

Obviously, a solution to the problem is to seek ways, other than land disposal, of beneficially utilizing the material. Since fresh paunch is a malodorous slurry, it must first be dried for easier handling and to remove the objectionable odor. Baumann (1,2) described the use of a mechical heat dryer for drying paunch. Additionally, chemical analyses were made on the dried product for various components. Table 1 shows the results of these analyses.

Table 1. Analyses of Dehydrated Paunch*

Percent	Mean	Std. Dev.	No. of Detm's.
Moisture	6.8	1.9	96
Protein	12.7	1.5	88
Fat	3.1	0.6	86
Carbohydrate**	40.8	5.3	44
Crude Fiber	26.2	3.2	88
Ash	7.2	0.7	88
Calcium	0.59	0.09	60
P_2O_5	1.47	0.25	60

*Taken from Baumann(2).
**Calculated by subtracting total percentage of moisture, protein, fat, crude fiber, and ash from 100 for each sample.

It is quite apparent that this waste material retains most of the nutritional value contained in cattle feed. Aside from the unfounded objection by some from the aesthetic viewpoint, that it would be logical to refeed the material to beef cattle requires no perspicaciousness. Indeed, refeeding of paunch and even chicken manure and cattle manure to cattle has been done successfully. One experiment in which dried paunch was used at various substitution rates to replace ground shelled corn or dehydrated alfalfa in rations for finishing cattle was described by Goodrich and Meiske(3). To increase usage and gain wider outlet for dehydrated paunch, it would be advantageous to seek additional species of animals for the recycling of the material. The channel catfish may be a most suitable vehicle for the recycling of paunch because of the following reasons:

1) Fish in general are more efficient in the conversion of feed into edible flesh.

2) Catfish are known to be omnivorous.

3) Commercial catfish farming has been and continues to be a rapidly growing industry in the U. S.

4) It has been documented that channel catfish will grow just as rapidly when fed with a ration consisting of a 50-50 mixture of 41 percent protein-cotton seed cake and feedlot manure as when fed with a ration consisting of 41 percent protein-cotton seed cake and milo.(4)

Nutritional studies have shown that feed with a protein content of 28-32 percent will produce the fastest growing channel catfish (5,6). Dried paunch, with a protein content of approximately 13 percent, will not suffice as a complete feed in channel catfish production, but could well be used as a feed supplement to replace some of the normally used constituents such as soybean meal, alfalfa meal, and cottonseed meal. It has been projected that commercial catfish production will reach 112.5 million pounds annually by 1975. Assuming a substitution rate of 25 percent dried paunch in commercial catfish feed, it is estimated that 45 percent of all the paunch produced by the meat industry in the country could by utilized through this outlet by 1975.

The following preliminary feasibility studies were made to provide information as to whether the above-mentioned idea of using dried paunch as a feed supplement in catfish culture merits further investigation.

AIR DRYING STUDIES

Although the project at Beefland International, Inc.(2) has demonstrated that it is practical to dry paunch mechanically with a heated dehydrator, the capital cost for the equipment can be prohibitive for the small meatpacker. Consequently, it was decided to investigate the feasibility of air drying the paunch. After placing the fresh paunch a 4-inch deep layer in a plastic pan and exposing the pan to sun and air, it was found that the surface dried rapidly, forming a crust, while underneath the crust the moisture remained for days and the material soon became moldy. By turning the material daily, the drying process was greatly accelerated and mold development was prevented. If turned daily, a 4-inch deep layer of paunch can be air dried within a week.

Subsequent experimentation was conducted on a larger scale by air drying paunch in a specially built concrete bed on the grounds of a local meatpacking plant. The overall measurements of the bed were 18 feet long by 9 feet wide, with an 8-inch high by 4-inch thick curb around the sides. The bed was divided equally into three separate compartments. A corrugated iron roof with a 4-foot overhang on all sides was erected over the bed to keep out rain water. Fresh paunch from the plant was spread on the bed to a depth of approximately four inches. The plan was to mix and turn over the material manually with a garden rake each day. The owner of the plant agreed to assign one of his employees to perform this task. However, this work amounted to an additional unpleasant chore to this employee and the assignment was not religiously carried out. The project's objective was to demonstrate that paunch can be air dried within a reasonable period in all seasons of the year under various kinds of weather conditions, but because of the above-mentioned flaw in this part of the work the results obtained were inconclusive. Moreover, the 4-foot overhang in the roof proved to be inadequate in keeping out rain water, and this prolonged the drying period in several instances. Nevertheless, four batches of paunch have been dried successfully; their moisture content after reaching equilibrium with the atmosphere ranged from 16 to 20 percent. The dried material was bagged in burlap feed sacks and stored in an open shed. The first batch has been stored in this manner for nine months with no evident signs of spoilage.

BIOCHEMICAL OXYGEN DEMAND STUDIES

Analysis of fresh paunch in the laboratory showed that after four weeks the material has a BOD of approximately 100,000 milligrams per 1,000 grams. Obviously, if dried paunch still exerts as much oxygen demand as the fresh material, its incorporation into catfish feed could be a matter of concern, since any of the uneaten feed would become a serious water pollutant. Accordingly, BOD tests were done on samples of air dried paunch. The results are shown in Figure 1. After 76 days, Sample 1 showed an oxygen uptake of 183,000 milligrams per 1,000 grams, with no indication of nitrification occurring until the 89th day. The oxygen uptake of Sample 2 was monitored for up to 131 days, with no sign of nitrification. The oxygen uptake after 131 days was 366,000 milligrams per 1,000 grams. The oxygen uptake for Sample 3 after 71 days was 258,000 milligrams per 1,000 grams. Again, there was no evidence of nitrification at the end of this period.

Clearly, the dried material has such an extended ultimate oxygen demand that a 5-day BOD of this organic material does not give a true picture of the extent of the problem created when the material is released and allowed to remain in a body of water. If an appreciable amount of the feed containing paunch remains uneaten, a serious water pollution problem could result, with consequent detriment to the fish due to oxygen depletion. In considering the use of paunch as a fish feed supplement, this important point definitely should not be overlooked.

SALMONELLA STUDIES

Decker and Steele(7) considered salmonellosis as one of the most important zoonoses transmitted by animal wastes. Hence, an attempt was made to determine the frequency of occurrence of Salmonellae in paunch freshly removed from the rumen of cattle slaughtered at a meat-packing plant. The fluorescent antibody (FA) technique as described by Fantasia (8) was compared with the conventional culture procedure.

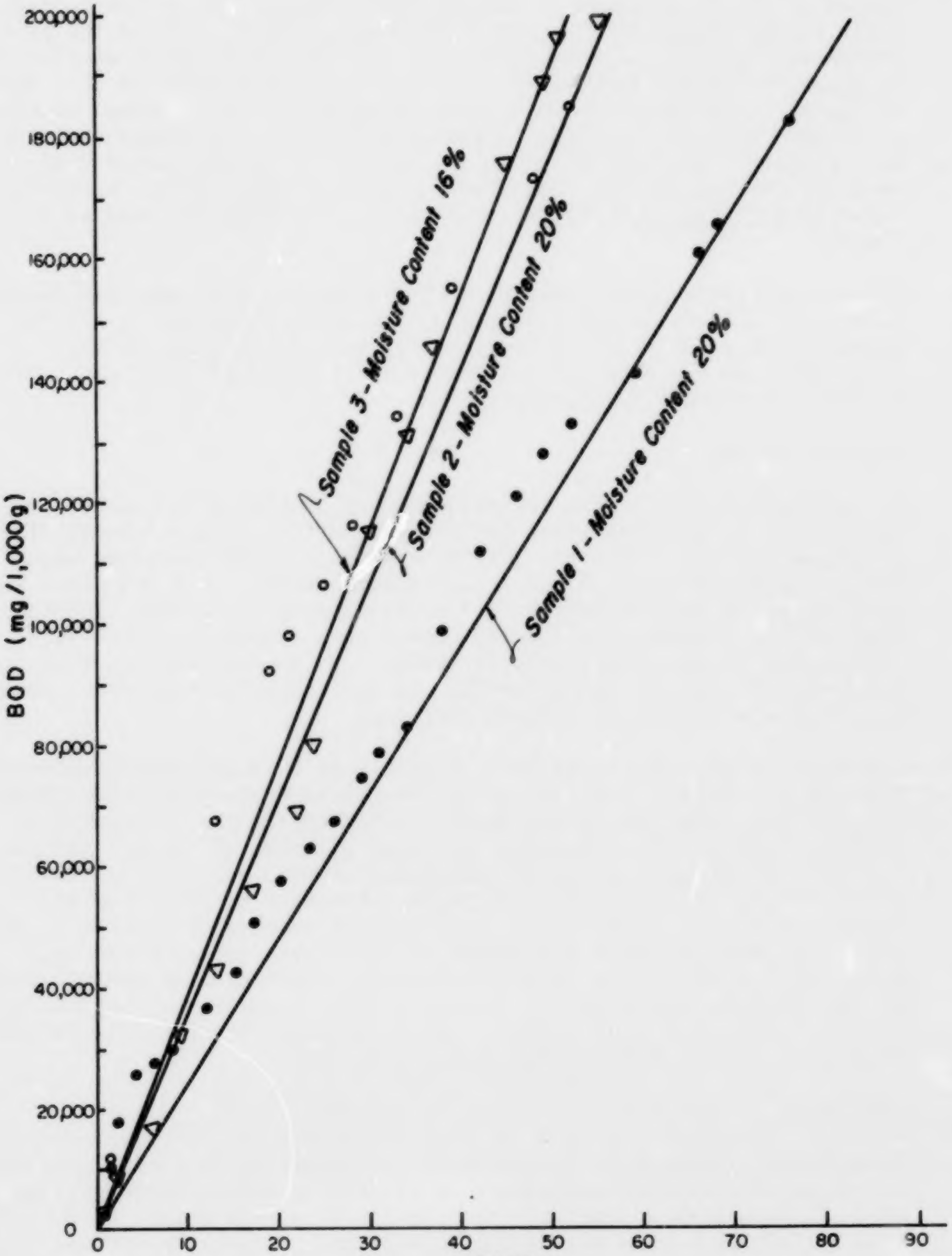

FIGURE 1 - BOD OF DRIED PAUNCH

In the culture procedure, 25 grams of the freshly collected paunch was placed in 225 milliliters of Lactose Broth (Difco) for pre-enrichment. After incubation at 37°C for 18 to 24 hours, 1 milliliter of the pre-enrichment culture was inoculated into a tube containing 10 milliliters of Selenite-Cystine Broth (Difco), followed by incubation at 37°C for 24 hours. This selective enrichment culture was then streaked on plates of SS Agar (Difco), Brilliant Green Agar (Difco), and Bismuth Sulfite Agar (Difco). After 24 hours' incubation at 37°C, the plates were examined for typical and suspected colonies of Salmonella. A strain of Salmonella typhimurium originally obtained from NCDC was used as a control.

A total of twelve paunch samples has been tested, with negative results. Because no Salmonella was isolated by the culture procedure, the FA method was abandoned, since any positive results obtained in this relatively new and experimental method would have had to be confirmed by the conventional culture procedure.

CATFISH STUDIES

An important factor in the determination of whether dried paunch is suitable as a feed supplement for channel catfish is the palatability of the material to the fish. Twelve channel catfish averaging about half a pound each were placed in laboratory tanks. After the fish were conditioned to the environment and to feeding on commercial floating catfish pellets, chunks of air-dried paunch were thrown into the tanks. The chunks floated on contact with the water, and it was observed that the fish readily consumed the material. It was concluded that dried paunch is acceptable to channel catfish as a food.

A full-scale experiment has been initiated at Oklahoma State University under an EPA grant. The project is designated Project No. 12060 HVQ and is under the direction of Dr. Robert C. Summerfelt and Dr. Austin K. Andrews, both at OSU. Open pond and cage cultures of channel catfish will be used to evaluate feeds containing several substitution levels of dried paunch. The feeds are specially formulated so that they will be isonitrogenous and isocaloric. This project represents a cooperative effort between OSU and EPA's Robert S. Kerr Water Research Center, since the latter will be mainly responsbile for the water quality studies of the ponds to determine the effects of the two different methods of catfish culture on water quality, and to evaluate the possible detrimental effects of paunch in fish feed on water quality.

DISCUSSION

These brief, preliminary studies have shown that it is feasible to use dried paunch as a feed supplement in catfish culture. Although, due to circumstances beyond control, inconclusive data with regard to actual time requirements were obtained on air drying, it was demonstrated that paunch can be air dried successfully, and the dehydrated product can be stored for months without spoilage. A mechanical device of some sort, perhaps a flail mower, to turn the paunch over regularly, would hasten the drying process, prevent the development of molds, and make it economically attractive for the small meat-packer. It appears unfeasible to keep flies from ovipositing on the paunch, but perhaps accelerating the drying process by daily turning will prevent the development of fly larvae and the subsequent pupae from emerging, thus, keeping the paunch drying bed from being a fly breeding ground(9).

Conceivably, dried paunch incorporated into fish feed could become a serious water pollutant if the feed remains in the water for a long period, due to the high ultimate BOD of the material. However, in fish culture the amount of feed given each day is based on a certain percentage (usually 2-3 percent) of the body weight of the fish for the most efficient growth. Presumably, all the feed given at each feeding is consumed by the fish within a short period. This is especially probable in pond culture, in which case the water polluting potential of dried paunch is of lessened concern. In suspended cage culture, the situation is somewhat different. Here, even though the feed used is of the floating type, the pellets will eventually sink after being placed in water, and once the pellets drift out of the confines of the cage the fish will not be able to retrieve them. When that happens, the dried paunch in the feed will definitely pollute the water, depleting the dissolved oxygen to the detriment of the fish. Studies done in the grant project will provide an answer as to whether this will be a problem.

No Salmonellae were isolated from the fresh paunch, which was somewhat unexpected. The absence of Salmonellae is likely due to the low pH of paunch, some samples of which have been found to have a pH as low as 5.6. Moreover, during the pre-enrichment culture in lactose broth, further fermentation occurs, the organic acids produced bringing the pH of the mixture after 24 hours' incubation to approximately 4.9 Because of the low pH, the material may be safe from contamination by pathogenic bacteria; however, this must be verified. It is still possible that successful isolation of Salmonellae can be accomplished when a more sensitive isolation method such as that described by Kenner, Dotson and Smith(10) is used. Further studies in this area are indicated.

The palatability of dried paunch to channel catfish will not surprise any catfish fisherman, who uses such baits as stink baits and chicken entrails to lure these fish. The catfish studies to be conducted at Oklahoma State University are expected to produce reliable and conclusive information on whether dried paunch is suitable as a feed supplement in channel catfish culture. If favorable results are obtained, it should bring about a demand for dried paunch in the rapidly expanding catfish farming industry, thereby converting this material from a troublesome waste which is a potentially serious water pollutant into a useful by-product which will help another industry to provide a tasty and nutritious food for mankind.

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CHARACTERIZATION OF FRUIT AND VEGETABLE PROCESSING WASTEWATERS*

by

M. R. Soderquist**, G. I. Blanton, Jr.** and D. W. Taylor***

INTRODUCTION

For the past two years, the Department of Food Science and Technology at Oregon State University has been monitoring the wastewaters from Willamette Valley fruit and vegetable processing plants. The data generated in the study are being used to augment existing knowledge of the volumes and characteristics of food processing effluents.

The need for such a study became evident when a state-wide processor survey and concurrent literature review indicated that although considerable information on fruit and vegetable processing waste streams was available, most of the data were either so general as to be of limited use or had been gathered in such a manner that reliance on them would be ill-advised. For example, many of the studies were conducted 20 to 30 years ago using "grab" samples gathered over short periods of time ranging from a few hours to a few days. Data gathered in this manner are of dubious validity, especially when one is dealing with food processing, where effluent strengths and flows often fluctuate wildly.

To indicate the reliance on historical rather than contemporary data, Table 1 was prepared. This table lists, for each of three commodities, the wastewater characteristics cited by four respected text and reference books dating from 1953 to 1971.

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**Department of Food Science and Technology, Oregon State University, Corvallis, Oregon.

***National Environmental Research Center, Environmental Protection Agency, Corvallis, Oregon.

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Table 1. Literature Values for End-of-pipe Wastewater Characteristics

Reference	Volume (gal/case)	BOD_5 (mg/l)	Suspended Solids (mg/l)
Whole kernel corn:			
Rudolfs (1)	25-70	1123-6025	300-4000
Gurnham (2)	25-70	1120-6300	300-4000
Lund (3)	25-70	1120-6300	300-4000
Nemerow (4)	25-70	1123-6025	300-4000
Red beets:			
Rudolfs (1)	27-65	1580-5480	740-2188
Gurnham (2)	27-70	1580-7600	740-2220
Lund (3)	27-70	1580-7600	740-2220
Nemerow (4)	27-65	1580-5480	720-2188
Green and wax beans:			
Rudolfs (1)	26-44	160-600	60-85
Gurnham (2)	26-44	160-600	60-150
Lund (3)	26-44	160-600	60-150
Nemerow (4)	26-44	160-600	60-85

While some minor variations in values are evident, the similarities are unmistakable. All but one of these references cited the same source of information, N. H. Sanborn (4), who was associated with the National Canners Association at the time he did that work. The remaining reference was Gurnham (2), in which the chapter on "Canned Foods" was authored by W. A. Mercer, also of the National Canners Association.

The fact that the values of Table 1 have remained essentially unchanged for nearly twenty years might be explained in at least two ways: 1) the numbers have remained valid and are applicable to today's processing plants; or 2) they have become out-dated, but nonetheless, have been transferred from publication to publication, apparently without adequate verification.

Sanborn was the author of the chapter on food processing in the early (1953) book edited by Rudolfs (1). The sources of Sanborn's values were not individually identified, but if it is assumed that they were included in his bibliography, where the publication dates varied from 1913 to 1948, perhaps it would be fair to say that the average wastewater characteristic in Sanborn's chapter was generated around 1940.

Specifics regarding methods and frequency of sampling and analysis were often unavailable to Sanborn; indeed he stated (1):

> "Details concerning the collection of samples are frequently lacking. It is believed that most, if not all, of the data were obtained after screening."

Data origins are difficult to pinpoint, but if the findings of this exercise are typical, many of the currently-used food processing wastewater characterization figures (because of their antiquity and questionable circumstances under which they were generated) may not warrant the confidence of those who rely on them. Thus, the need for contemporary wastewater quantity and quality analyses was recognized by the authors. This need was underscored in a recent publication on "Research Needs in Sanitary Engineering" (5) by the Sanitary Engineering Research Committee of the American Society of Civil Engineers:

> "Industrial wastes are typically less well identified [than sanitary sewage]... All of these waste streams must be more completely characterized to insure optimum environmental control by focusing attention on the most significant problem areas."

THE FIRST SEASON

In 1970 the authors began the task of supplementing and verifying (or refuting) existing data by developing wastewater quantity and quality profiles for each of Oregon's major commodity-process combinations. Analyses were conducted as prescribed by Standard Methods (9) except phosphorus determinations, where the methods of Jankovic, et al. (10) were followed. All samples were screened (20 mesh) prior to analysis. Since a newly-constructed (and untested) mobile laboratory (6) was to be employed, a processing plant in close proximity to the O.S.U. campus was chosen. This would minimize the inconvenience of altering, repairing and "debugging" the new laboratory. Hindsight reveals that this criterion should have been assigned a lower priority than some others, most notably plant layout. It soon became apparent that the plant's physical configuration presented difficult problems to the wastewater sampling technician. In many cases the collection of discrete samples from single commodity unit-operations was impossible; in those instances, samples containing wastewaters from the simultaneous processing of more than one commodity were taken.

Since this paper is limited to the presentation of data from the processing of single commodities, not many of the results of the first season's efforts are included. Consequently, because of the small numbers of datum points involved, statistical analyses of these results have not been attempted.

Corn

The plant processed several commodities, including sweet corn, beets, green beans, purple plums and red sour cherries, but only corn and beets were processed discretely.

The corn was husked, trimmed, washed, cut from the cob, de-silked, and washed again. Then it was canned (whole-kernel) and retorted. A total of nine days' "corn-only" processing yielded the data of Table 2.

Table 2. Total Plant Effluent Characteristics During Corn Processing

Parameter	Mean	Range
Flow (gpm)	207.5	121.9-317.8
(gpT)	1307	813-2002
(gal/case)	40.8	25.4-62.6
COD (lb/Ton)	34.38	32.99-35.89

In this table, flow was expressed in terms of gallons per standard case (24 number 303 equivalent cans) by using the yield value found in the latest "Yearbook" issue of Canner-Packer magazine (7). The range of water usage expressed in that manner compares well with its counterparts in Table 1, indicating that the published water usage figures for whole-kernel corn processing were applicable to this processing plant in 1970.

When considering wastewater constituents expressed in terms of concentration (e.g., mg/l or ppm) one should avoid direct comparisons among plants or even among different processing periods within the same plant. The reasons for this are many; one of the most obvious is the influence of production on waste load. In most processing operations water usage is not proportional to product throughput. The flow through each unit is either constant or increases from a significant (non-zero) base level as some (often non-linear) function of production. Therefore it is preferable to express wastewater constituents in terms of production, as is COD in Table 2.

Comparison of the COD values of Table 2 with the BOD values of Table 1 is difficult because Table 1 lists concentrations. One can convert the BOD values of Table 1 to equivalent COD's using the BOD:COD ratio, 0.75, found to be applicable in this study to combined (end-of-pipe) corn waste. Subsequent conversion to a production basis, however, becomes more difficult to defend. It is common knowledge that in a waste stream, pollutant concentration more nearly approximates an inverse function of water usage than a direct one. Both functions, however, are poor estimates of reality. In Table 3 the data of Table 1 have been manipulated variously to illustrate the problems discussed above. In the first two lines are expressed the two ranges of BOD listed in Table 1, that of Rudolfs (1) and Nemerow (4) being designated (a) and that of Gurnham (2) and Lund (3), (b). In the next pair of lines BOD has been converted to COD using the BOD/COD ratio (0.75). The next two lines list COD's based on production under the (admittedly unrealistic) assumption labeled "Case I": that the lowest concentrations occurred at periods of minimum flow and the highest concentrations at peak flow. Although this assumption is unreasonable, it sometimes

Table 3. Literature Corn Waste Organic Values Expressed by Alternative Methods

Parameter		Range	Median
BOD (mg/l)	(a)	1123-6025	3574
	(b)	1120-6300	3710
COD (mg/l)	(a)	1498-8034	4765
	(b)	1493-8400	4947
Case I*: COD (lb/T)	(a)	9.98-150.02	80.00
	(b)	9.96-156.87	83.42
Case II**: COD (lb/T)	(a)	27.97-53.58	40.78
	(b)	27.89-56.02	41.96

*Minimum concentration occurs at minimum flow and maximum at maximum flow

**Minimum concentration occurs at maximum flow and maximum at minimum flow

appears in the literature. Case II, then, lists the "opposite" assumption (which, although more nearly correct, is also inaccurate): that low concentrations coincide with peak flows and peak concentrations, with low flows.

Based on Case II, then, the COD values of Table 2 do fall well within the ranges derived from the values reported in the literature (Table 3).

Beets

Red beet processing at this plant involved washing, peeling, blanching, slicing (or dicing), canning and retorting. The initial wash water was heavily laden with suspended solids; four to five percent of the incoming raw product weight was attributable to soil, most of which was removed in the initial washing.

As with corn, nine days' "beets only" processing led to the flow data of Table 4. Using a yield of 70 standard cases per raw product ton (7), the flows expressed on a case basis were calculated. Comparing these flows with their counterparts in Table 1 reveals the mean from the current work to fall completely below the ranges quoted in the earlier literature. In fact, the upper end of the current range barely falls within the lower range of the earlier literature values.

During beet processing only two 24-hour flow proportioned "beets only" samples were analyzed for chemical oxygen demand. The results of those analyses also are listed in Table 4. As with corn, to facilitate comparing these current values with those of the older literature, Table 5 was prepared similarly to Table 3.

Table 4. Total Plant Effluent Characteristics During Beet Processing

Parameter	Mean	Range
Flow (gpm)	292.8	249.8-353.5
(gpT)	1655	1410-1998
(gal/case)	24.8	21.1-29.9
COD (lb/Ton)	74.8	68.0-81.7

Table 5. Literature Beet Waste Values Expressed by Alternate Methods

Parameter		Range	Median
BOD (mg/l)	(a)	1580-5480	3530
	(b)	1580-7600	4590
COD* (mg/l)	(a)	1816-6299	4058
	(b)	1816-8736	5276
Case I**: COD (lb/T)	(a)	28.61-238.94	133.78
	(b)	28.61-356.88	192.75
Case II**: COD (lb/T)	(a)	68.89-99.25	84.07
	(b)	75.00-137.65	106.33

*BOD/COD = 0.87
**See footnotes for Table 3.

Based on Case II, the COD values of Table 4 fall on the lower part of the range of values expressed in the older literature.

Tables 6 and 7 offer a comprehensive breakdown of the wastewaters from the two isolable unit operations within the beet canning process: raw product washing and blanching-peeling. Eight flow-proportioned composite samples were analyzed in each case. In this plant the washing process contributed 17 percent of the flow, containing only 2 percent of the COD. Therefore it would little behoove the processor to attempt reduction of his overall organic loading by modifying the washing operation. The blanching-peeling process, however, was another matter, where 39 percent of the total plant outflow contained 85 percent of the COD. This operation, then, would be a logical starting point for effective overall organics reduction.

Table 6. Beet Wash Effluent Characteristics

Parameter	Mean	Range
Flow (gpm)	50.0*	-----
(gpT)	281.2	216.4-421.4
(gal/case)	4.0	3.1-6.0
COD (lb/Ton)	1.7	0.1-7.9
Total phosphorus (lb/Ton)	0.033	0.012-0.049
Total inorganic phosphorus (lb/Ton)	0.020	0.007-0.033
Orthophosphate (lb P/Ton)	0.004	0.002-0.008
Ammonia (lb N/T)	0.002	0-0.003
Organic nitrogen (lb/T)	0.010	0-0.028

*constant flow

Table 7. Beet Blanching and Peeling Effluent Characteristics

Parameter	Mean	Range
Flow (gpm)	114.6*	-----
(gpT)	659.4	495.9-1339.7
(gal/case)	9.4	7.1-19.1
COD (lb/Ton)	63.5	45.6-104.7
Total phosphorus (lb/Ton)	0.156	0.118-0.203
Orthophosphate (lb P/Ton)	0.139	0.116-0.154
Ammonia (lb N/Ton)	0.091	0.069-0.120
Organic nitrogen (lb/Ton)	0.144	0.023-0.259
	0.075	0.014-0.151

*constant flow

Relatively little phosphorus and nitrogen were contributed to the plant effluent by these unit operations. Washing produced 0.033 lb P/ton raw product and 0.012 lb Kjeldahl N/ton, whereas blanching and peeling contributed 0.156 lb P/ton and 0.219 lb K-N/ton. With a BOD/COD relationship of 0.87, the BOD:N:P ratio for washing becomes approximately 45:0.4:1. Likewise, the ratio for blanching-peeling becomes 354:1.4:1.

For satisfactory biological treatment, a minimal ratio is said to be around 150:5:1 (8). This indicates that, if necessary, the wash water could be treated biologically with only nitrogen addition, whereas the blancher-peeler waste stream would require singificant nitrogen and phosphorus addition prior to treatment.

With both corn and beets the COD measured per ton of product was lower in the present study than in the literature. This can be attributed in large part to the reduced water usage (per ton of product) in today's canneries when compared with those of twenty years ago. Water use reduction generally reduces product-water contact time and thereby reduces leaching.

THE SECOND SEASON

During the 1971 processing season the mobile laboratory was located at a large processing plant where the processing lines for the various commodities were distinct and well separated. This facilitated the collection of representative samples from each major unit operation without risk of interference from other commodities.

The processes monitored included the canning of Lambert and Royal Anne cherries, green beans and Bartlett pears. In most cases, sufficient numbers of samples were collected to permit statistical analyses of the analytical results. These analyses resulted in means, ranges and standard deviations for sixteen different parameters, each of which was expressed (where appropriate) both as a concentration and on a raw product tonnage basis.

Green Beans

As shown on Figure 1, the green bean canning process involved an initial washing followed by grading, snipping of ends (in Chisholm Ryder* snippers), cutting, blanching (in rotary water blanchers), canning and retorting. A subsequent paper will review the complete results of the green bean characterization; emphasis here is placed on the end-of-pipe effluent plus the major contributors to the total pollution load: the washing and grading and the blanching processes.

Table 8 presents the characteristics of the total process effluent. Standard deviations are not listed on this table because it represents a summation of the means, maxima and minima from the sub-processes. It is interesting that the per case flows fell completely below the range quoted in the earlier literature (Table 1) supporting the theory that present-day canneries are more conservative in their water consumption practices than in the 1940's.

When the BOD values of Table 1 are expressed in terms of raw product tonnage (assuming a Case II function) they become: 7.34 to 16.25 lb/T. The BOD values of Table 8 fall below that range, leading to the same conclusion mentioned earlier with respect to corn and beets.

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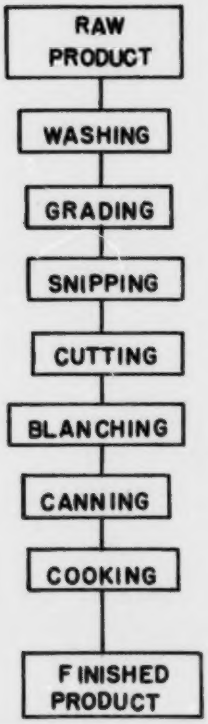
*Note Disclaimer at end of paper.



RAW PRODUCT
WASHING
GRADING
SNIPPING
CUTTING
BLANCHING
CANNING
COOKING
FINISHED PRODUCT

Figure 1. Snap Bean Processing

Table 8. Total Plant Effluent Characteristics During Green Bean Processing (19 samples).

Parameter	Mean	Range
Flow (gpm)	788	685-924
(gpT)	2488	2163-2916
(gal/case)*	19.90	17.30-23.33
COD (lb/T)	6.81	4.93-10.36
BOD/COD	0.53	----
BOD** (lb/T)	3.61	2.61-5.49
Total Solids (lb/T)	9.66	7.13-13.82
Suspended Solids (lb/T)	2.68	1.57-4.55
Settleable Solids (ml/l)	1.5	0.1-5.0
Total Nitrogen*** (lb/T)	0.2238	0.1649-0.2966
NO_3^- (lb-N/T)	0.0073	0.0033-0.0110
NO_2^- (lb-N/T)	0	----
NH_3 (lb-N/T)	0.0065	0.0026-0.0136
Organic N (lb/T)	0.210	0.159-0.272
Total Phosphorus (lb/T)	0.0430	0.0288-0.0562
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0218	0.0136-0.0299
Inorganic P (lb/T)	0.0297	0.0215-0.0433
Total Soluble P (lb/T)	0.0356	0.0203-0.0443
pH	6.1	5.1-7.1
Dissolved Oxygen (mg/l)	7.9	6.5-8.4
Temperature (°C)	28.0	25.8-31.3

*Calculated on a yield basis of 125 cases/ton (7).
**Calculated from COD by using BOD/COD ratio.
***Calculated by summing components.

From Table 8 the BOD:N:P ratio of 84:5:1 can be calculated. Remembering the (nutrient) minimum ratio to be 150:5:1, the bean processing waste appears not to be nutrient deficient from the standpoint of biological waste treatment. It should be noted, however, that only 6.2 percent of the nitrogen was in the more assimilable inorganic form (2.9 percent ammonia), whereas 83 percent of the phosphorus was in the more-readily-utilized soluble form.

The volatile(combustible) content of the total solids in the combined effluent was 73 percent. In terms of total solids and suspended solids, the unit operation having the greatest impact on the overall waste load was the washing-grading process, as shown in Table 9. For example, 77 percent of the total bean process suspended solids load was contributed in this step. The low volatile solids content (38 percent) and a visual inspection of the solids substantiated the conclusion that this was primarily soil, which had been transported with the beans from the field. The washing-grading sub-process also contributed large volumes of wastewater (20.9 percent of the total) to the system, being second only to clean-up (32.6 percent of the total) and retorting (29.0 percent).

Table 9. Green Bean Washing and Grading Process Effluent Characteristics

Parameter	Mean	Range	Std. Deviation	% of Total
Flow (gpm)	164	148-191	23.3	--
(gpT)	519	467-603	73.5	20.9
(gal/case)*	4.15	3.74-4.82	--	---
COD (lb/T)	1.27	0.74-1.89	0.58	18.6
BOD** (lb/T)	0.67	0.39-1.00	--	---
Total Solids (lb/T)	3.09	2.23-4.68	1.38	32.0
Settleable Solids (ml/l)	4.5	3.0-7.0	1.3	---
Suspended Solids (lb/T)	2.07	1.25-3.57	1.31	77.0
Total Nitrogen*** (lb/T)	0.0564	0.0458-0.0650	--	25.2
NO_3^- (lb-N/T)	0.0014	0.0008-0.0020	0.0008	19.2
NO_2^- (lb-N/T)	0.0000	---	--	---
NH_3 (lb-N/T)	0.0000	----	--	0.0
Organic N (lb/T)	0.0550	0.0450-0.0630	0.0090	26.2
Total Phosphorus (lb/T)	0.0120	0.0090-0.0160	0.0050	27.9
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0038	0.0034-0.0041	0.0005	17.4
Inorganic P (lb/T)	0.0076	0.0054-0.0097	0.0030	25.6
Total Soluble P (lb/T)	0.0079	0.0047-0.0111	0.0045	22.2
pH	7.1	6.8-7.5		---
Dissolved Oxygen (mg/l)	9.7	8.4-10.4	0.64	---
Temperature (°C)	17.7	14.8-20.3	1.37	---

*Calculated on a yield basis of 125 cases/ton (7).
** Calculated from COD using BOD/COD = 0.53.
*** Calculated by summing components.

As was expected, the greatest contributor to the plant wastewater system in terms of COD, nitrogen and phosphorus was the blanching operation, which is characterized in Table 10. The rotary water blanchers generated 44 percent of the total process COD (hence, BOD) in this instance. The total solids level was comparable to the previous unit operation, but volatile solids increased from 73 to 79 percent. The blanchers were the major sources of nitrogen and phosphorus, producing, for example, 63 percent of the ammonia and 43 percent of the orthophosphate found in the combined wastewater stream. The BOD:N:P ratio for this sub-process was 109:6:1. 93 percent of the total nitrogen was in the organic form whereas 89 percent of the total phosphorus was in the soluble form.

Table 10. Green Bean Water Blanching Effluent Characteristics* (7 samples)

Parameter	Mean	Range	% of Total
Flow (gpm)	49.0	20.9-70.4	---
(gpT)	107.0	45.6-153.6	4.3
(gal/case)**	0.86	0.36-1.23	---
COD (lb/T)	2.99	1.78-4.05	43.9
BOD*** (lb/T)	1.58	0.94-2.15	---
Total Solids (lb/T)	2.93	1.85-3.86	30.3
Suspended Solids (lb/T)	0.19	0.16-0.27	7.1
Settleable Solids (ml/l)	5.7	2.8-10.0	---
Total Nitrogen**** (lb/T)	0.0827	0.0571-0.1153	37.0
NO_3^- (lb-N/T)	0.0016	0.0012-0.0023	21.9
NO_2^- (lb-N/T)	0.0000	---	---
NH_3 (lb-N/T)	0.0041	0.0029-0.0070	63.1
Organic N (lb/T)	0.0770	0.0530-0.1060	36.7
Total Phosphorus (lb/T)	0.0145	0.0099-0.0189	33.7
Ortho-$PO_4^{\equiv}$	0.0094	0.0063-0.0112	43.1
Inorganic P (lb/T)	0.0114	0.0081-0.0134	38.4
Total Soluble P (lb/T)	0.0129	0.0081-0.0171	36.2
pH	6.0	4.9-6.6	----
Dissolved Oxygen (mg/l)	0.0	---	---
Temperature (°C)	68.6	64.5-71.0	---

*Insufficient data (seven samples) for valid determination of standard deviation.

**Calculated on a yield basis of 125 cases/T (7)

***Calculated from COD using BOD/COD = 0.53

****Calculated by summing components

Cherries

Two different varieties of sweet cherry, Royal Anne and Lambert, were processed at this plant. A comparison of Figures 2 and 3 reveals that the processing methods were similar with one exception: stemmers (Atlas Pacific) were used with the Royal Annes, whereas none were needed for the Lambert cherries which were received stemless. The similarity of processing methods permitted investigation of varietal and ripeness influences on wastewater composition. The results were impressive; markedly different wastewater streams resulted.

Royal Anne Cherries: As shown on Table 11, the canning of Royal Anne cherries required 1510 gallons of water per ton of raw product. This 1510 gallons contained organics which would exert about 28 lbs COD; they also contained about 27 lbs total solids (of which about 80 percent was volatile). The solids were largely soluble or colloidal, indicating that further screening (beyond the 20 mesh screening that all samples received prior to analysis) would be useless.

Compared to snap beans, then, Royal Anne cherries contributed (on a production basis) more than four times the COD (hence, BOD) and nearly three times the solids, while requiring only about 60 percent of the process water volume per ton of raw product.

When considering the unit operations within the Royal Anne canning line, one notes that in nearly every category the major contributors to the wastewater loads were the Dunkley pitters. When Table 12 is compared with Table 11, these units appear to have contributed more than 90 percent of every contaminant except phosphorus. However, although the pitters were certainly the greatest source of all wastewater constituents, it should be noted that only 17 percent of the total Royal Anne cherry throughput was pitted. This means that the total plant effluent, representing the results of production throughout the season, cannot be directly compared with the pitter effluent. Nevertheless, it seems a valid conclusion that the pitter effluent (volatile solids = 96 percent) might best be handled by segregation and separate treatment and/or by-product recovery.

The only unit operation not common to both the Royal Anne and the Lambert cherry processing lines was stemming. The Royal Annes were handled in Atlas Pacific stemmers. These units were the second-highest water users in the process line (the first being the continuous cookers). This water usage was about 570 gallons per ton of fruit processed. Investigation of Table 13 indicates the contribution of all contaminants from the stemmers, however, to have been minor. The volatile solids level was 74 percent.

Lambert Cherries: Varietal differences and/or degree of ripeness (hence juice volume) were detectable between the Lambert and Royal Anne cherries in that these differences were reflected strongly in the wastewater characteristics. Table 14 presents the data from the Lambert process. Although the water usage was only two-thirds that of the Royal Annes', the COD contribution was up 30 percent and the total solids, 35 percent

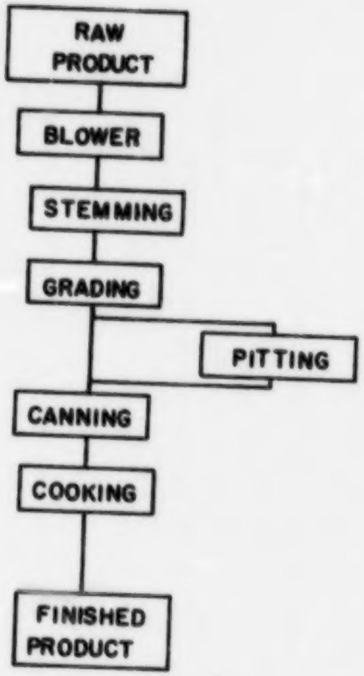

RAW PRODUCT
BLOWER
STEMMING
GRADING
PITTING
CANNING
COOKING
FINISHED PRODUCT

Figure 2. Royal Anne Cherry Processing

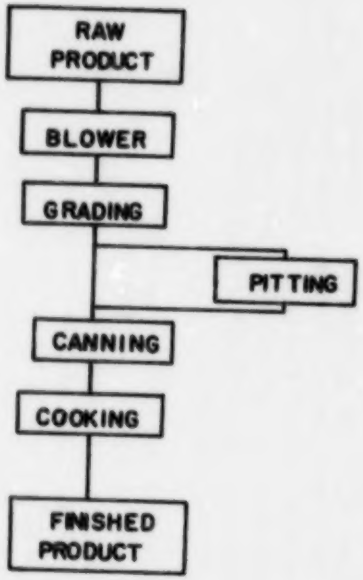

RAW PRODUCT
BLOWER
GRADING
PITTING
CANNING
COOKING
FINISHED PRODUCT

Figure 3. Lambert Cherry Processing

Table 11. Total Plant Effluent Characteristics During Royal Anne Cherry Processing (7 samples).

Parameter	Mean	Range
Flow (gpm)	251.6	166.6-319.2
(gpT)	1510	1000-1955
(gal/case)*	13.85	9.17-17.94
COD (lb/T)	27.73	19.95-34.65
BOD** (lb/T)	15.53	11.17-19.40
Total Solids (lb/T)	27.17	20.87-33.99
Suspended Solids (lb/T)	0.87	0.15-1.59
Settleable Solids (ml/l)	1.5	0.4-3.5
Total Nitrogen*** (lb/T)	0.1631	0.0912-0.2818
NO_3^- (lb-N/T)	0.0081	0.0031-0.0159
NO_2^- (lb-N/T)	0.0000	---
NH_3 (lb-N/T)	0.0493	0.0032-0.1394
Organic N (lb/T)	0.1057	0.0849-0.1265
Total Phosphorus (lb/T)	0.0388	0.0180-0.0660
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0152	0.0080-0.0279
Inorganic P (lb/T)	0.0153	0.0077-0.0276
Total Soluble P (lb/T)	0.0225	0.0133-0.0325
pH	6.2	5.6-6.9
Dissolved Oxygen**** (mg/l)	8.4	7.7-8.8
Temperature (°C) (excluding cookers)	25.3	22.0-26.0
(including cookers)	32.8	29.0-34.8

*Calculated on a yield basis of 109 cases/ton (7); 17% of throughput was pitted.

**Calculated from COD by using BOD/COD ratio of 0.56.

***Calculated by summing components.

****Excluding cooker flow, where D.O. was 0 mg/l.

Table 12. Royal Anne Cherry (Dunkley) Pitter Effluent Characteristics

Parameter	Mean	Range	Std. Deviation
Flow (gpm)	29.8	22.5-37.0	73.0
(gpT)	1983 *	750-3700	1533
(gal/case)**	18.19	6.88-3.94	---
COD (lb/T)	26.32	19.17-32.59	6.75
BOD*** (lb/T)	14.74	10.74-18.25	---
Total Solids (lb/T)	25.49	19.82-31.59	5.90
Suspended Solids (lb/T)	0.83	0.12-1.53	0.70
Settleable Solids (ml/l)	10.1	5.2-15.0	6.9
Total Nitrogen**** (lb/T)	0.1608	0.0900-0.2784	---
NO_3^- (lb-N/T)	0.0078	0.0030-0.0154	0.0067
NO_2^- (lb-N/T)	0.0000	---	---
NH_3 (lb-N/T)	0.0490	0.0030-0.1390	0.0780
Organic N (lb/T)	0.1040	0.0840-0.1240	0.0280
Total Phosphorus (lb/T)	0.0510	0.0120-0.0560	0.0220
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0110	0.0050-0.0220	0.0090
Inorganic P (lb/T)	0.0110	0.0050-0.0220	0.0090
Total Soluble P (lb/T)	0.0170	0.0090-0.0250	0.0110
pH	4.3	4.2-4.3	
Dissolved Oxygen (mg/l)	10.0	10.0-10.2	0.1
Temperature (°C)	15.8	15.5-16.0	0.3

*Only 17% of the total cherry pack was pitted; therefore "% of Total" column omitted.

**Calculated on a yield basis of 109 cases/ton (7).

***Calculated from COD by using BOD/COD ratio of 0.56.

****Calculated by summing components.

Table 13. Royal Anne Cherry (Atlas-Pacific) Stemmer Effluent Characteristics

Parameter	Mean	Range	Std. Deviation	% of Total
Flow (gpm)	94.71	77.0-112.0	11.4	---
(gpT)	568.	462-672	69.	37.6
(gal/case)*	5.21	4.24-6.17	---	---
COD (lb/Ton)	0.67	0.38-0.90	0.19	2.4
BOD** (lb/Ton)	0.38	0.21-0.50	---	---
Total Solids (lb/Ton)	0.91	0.62-1.17	0.25	3.3
Suspended Solids (lb/Ton)	0.027	0.020-0.036	0.01	3.1
Settleable Solids (ml/l)	0.06	0-0.1	0.02	---
Total Nitrogen*** (lb/T)	0.0000	---	---	0.0
NO_3^- (lb-N/T)	0	---	---	0
NO_2^- (lb-N/T)	0	---	---	0
NH_3 (lb-N/T)	0	---	---	0
Organic N (lb/T)	0	---	---	0
Total Phosphorus (lb/T)	0.0065	0.0052-0.0077	0.0018	16.8
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0032	0.0024-0.0042	0.0009	21.1
Inorganic P (lb/T)	0.0032	0.0020-0.0041	0.0011	20.9
Total Soluble P (lb/T)	0.0043	0.0035-0.0054	0.0010	19.1
pH	6.1	5.2-6.8	0.6	---
Dissolved Oxygen (mg/l)	10.0	9.0-10.2	0.5	---
Temperature (°C)	16.1	15.0-17.8	1.0	---

*Calculated on a yield basis of 109 cases/ton (7); 17% of throughput was pitted.

**Calculated from COD by using BOD/COD ratio of 0.56.

***Calculated by summing components.

(67 percent of the total solids were combustible organics). In comparison to snap bean processing, Lambert processing contributed more than five times the COD and nearly four times the total solids, on a production basis.

Like the Royal Anne, the Lambert cherry contributed the greatest portion of each pollutant at the Dunkley pitters, as shown on Table 15. Interestingly enough, the volatile solids percentage of the Lambert pitter effluent was identical to that of the combined effluent: 67 percent. By contrast, the Royal Anne pitter effluent volatile solids level was 96 percent or about 1.2 times that of the Royal Anne combined effluent. Since pitter effluent is mainly diluted cherry juice, it can be concluded from the above that the Royal Anne juice contained fewer inorganics and higher levels of combustible organics (such as sugars) than the Lamberts. The difference, then, between the Royal Anne effluent COD (28 lb/ton) and the Lambert effluent COD (37 lb/ton) might be attributed to differences in sugar content of the cherry juices, and to differences in cherry juice volumes lost in the respective processes.

Table 14. Total Plant Effluent Characteristics During Lambert Cherry Processing (15 samples).

Parameter	Mean	Range
Flow (gpm)	182.6	101.7-253.9
(gpT)	913.	509-1270
(gal/case)*	8.38	4.67-11.65
COD (lb/T)	36.71	29.90-46.64
BOD** (lb/T)	21.65	17.64-27.52
Total Solids (lb/T)	37.18	24.82-46.21
Suspended Solids (lb/T)	1.08	0.61-1.79
Settleable Solids (ml/l)	5.1	0.2-12.0
Total Nitrogen*** (lb/T)	0.1481	0.0474-0.2317
NO_3^- (lb-N/T)	0.0153	0.0071-0.0308
NO_2^- (lb-N/T)	0.0000	---
NH_3 (lb-N/T)	0.0099	0.0042-0.0169
Organic N (lb/T)	0.1229	0.0361-0.1840
Total Phosphorus (lb/T)	0.0705	0.0573-0.0836
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0575	0.0492-0.0673
Inorganic P (lb/T)	0.0628	0.0572-0.0708
Total Soluble P (lb/T)	0.0617	0.0452-0.0759
pH	5.6	5.0-6.0
Dissolved Oxygen (mg/l)	8.4	7.2-8.8
Temperature (°C)	25.6	22.0-28.5

*Calculated on a yield basis of 109 cases/ton (7); 17% of throughput was pitted.

**Calculated from COD by using BOD/COD ratio of 0.59.

***Calculated by summing components.

Bartlett Pears

The final commodity monitored during the second season was the Bartlett pear. This study offered the opportunity to compare the pollutional effects of two different types of mechanical peeling systems: the older Ewald peelers and the more modern (Atlas Pacific) contour peelers.

Table 15. Lambert Cherry (Dunkley) Pitter Effluent Characteristics (15 samples).

Parameter	Mean	Range	Std. Deviation
Flow (gpm)	41.5	30.0-50.5	6.1
(gpT)	1081. *	717-1900	341.
(gal/case)**	9.91	6.57-17.43	---
COD (lb/T)	36.26	29.78-45.46	5.76
BOD*** (lb/T)	21.39	17.57-26.82	---
Total Solids (lb/T)	36.72	24.60-45.02	5.75
Suspended Solids (lb/T)	1.07	0.61-1.75	0.36
Settleable Solids (ml/l)	8.1	0.4-25.0	8.2
Total Nitrogen**** (lb/T)	0.1409	0.0472-0.2029	---
NO_3^- (lb-N/T)	0.0150	0.0070-0.0300	0.0070
NO_2^- (lb-N/T)	0.0000	---	---
NH_3 (lb-N/T)	0.0099	0.0042-0.0169	0.0045
Organic N (lb/T)	0.1160	0.0360-0.1560	0.0320
Total Phosphorus (lb/T)	0.0690	0.0570-0.0770	0.0070
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0570	0.0490-0.0660	0.0060
Inorganic P (lb/T)	0.0620	0.0570-0.0690	0.0030
Total Soluble P (lb/T)	0.0610	0.0450-0.0740	0.0080
pH	4.6	4.3-4.9	
Dissolved Oxygen (mg/l)	9.9	8.7-10.4	0.6
Temperature (°C)	16.0	14.0-18.5	1.0

*Only 17% of the total cherry pack was pitted; therefore the "% of Total" column was not applicable to these data.

**Calculated on a yield basis of 109 cases/ton (7).

***Calculated from COD using BOD/COD ratio of 0.59.

****Calculated by summing components.

While the former peel the fruit by slicing over a pre-set contour, the latter follow the specific contour of each pear, abrading the fruit and thereby increasing the yield of saleable product by as much as 10 percent. It was interesting to discover that, in this case, the newer design was decidedly inferior to the older in waste management terms.

Figure 4 depicts the pear canning process. After initial grading, the pears were peeled and then flumed in a sodium chloride brine (which retarded the browning reaction on the peeled surfaces) to a fresh water rinsing tank for removal of excess brine solution. After rinsing, the pears were conveyed to trimming tables where blemishes were removed. Severely disfigured pears were directed after trimming from the main process line to the "chopping" area, there to be processed for incorporation

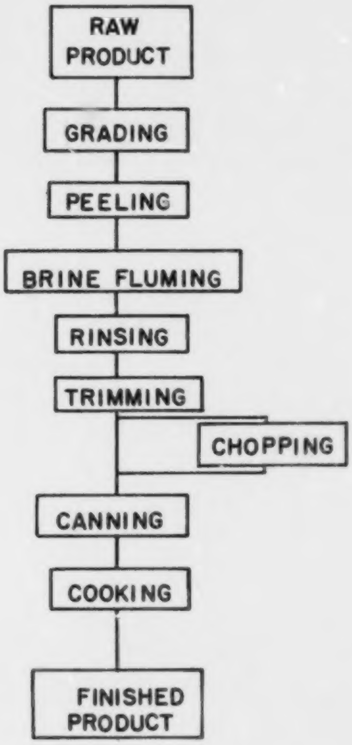

RAW PRODUCT
GRADING
PEELING
BRINE FLUMING
RINSING
TRIMMING
CHOPPING
CANNING
COOKING
FINISHED PRODUCT

Figure 4. Bartlett Pear Canning

into other types of products. After trimming, the fruit was canned and cooked in FMC continuous cookers.

The total pear process effluent exhibited the characteristics listed in Table 16. The process required about 2850 gallons of water per ton and the wastewater contained nearly 57 lbs total solids per ton (91 percent volatile), about 95 percent of which was colloidal or soluble; 55 lbs COD were exerted per ton of raw product.

The pear wastes were, therefore, the strongest (in terms of chemical oxygen demand) encountered in the second season, being about 1.5 times stronger than those of Lambert cherries, 2.0 times stronger than Royal Annes and 8 times stronger than green bean wastes. In both seasons'

Table 16. Total Plant Effluent Characteristics During Bartlett Pear Processing (24 samples).

Parameter	Mean	Range	Std. Deviation
Flow (gpm)	299.	230-399	---
(gpT)	2853.	1644-3249	---
(gal/case)*	35.05	20.20-39.91	---
COD (lb/T)	54.58	42.34-67.25	8.88
BOD** (lb/T)	29.47	22.86-36.32	---
Total Solids (lb/T)	56.87	40.83-67.53	8.86
Suspended Solids (lb/T)	2.82	1.89-3.87	0.51
Settleable Solids (ml/l)	43.7	34.0-55.0	8.7
Total Nitrogen*** (lb/T)	0.2615	0.0883-0.3114	---
NO_3^- (lb-N/T)	0.0540	0.0328-0.0727	0.0120
NO_2^- (lb-N/T)	0.0000	---	---
NH_3 (lb-N/T)	0.0039	0.0000-0.0069	0.0026
Organic N (lb/T)	0.2036	0.1555-0.2318	0.0277
Total Phosphorus (lb/T)	0.0473	0.0306-0.0642	0.0091
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0297	0.0210-0.0396	0.0049
Inorganic P (lb/T)	0.0367	0.0265-0.0473	0.0059
Total Soluble P (lb/T)	0.0378	0.0263-0.0470	0.0057
pH	4.4	4.1-5.3	
Dissolved Oxygen (mg/l)	9.7	8.5-10.3	0.5
Temperature (°C)	17.4	14.5-19.5	1.0

*Calculated on a yield basis of 81.4 cases/ton (7).

**Calculated from COD using BOD/COD ratio of 0.54.

***Calculated by summing components.

activities, the only stronger wastes were those emanating from the beet canning process of the first season (75 lb COD/ton).

Tables 17 and 18 compare the effluents from the two types of peelers. It can be seen that the newer-type contour peelers generated more than twice the COD and total solids loads of the Ewald peelers. It is unfortunate (from a pollution control standpoint) that the Ewald peelers (being no longer available on the market) are being phased out of the industry.

Table 17. Bartlett Pear Mechanical (Ewald) Peeler Effluent Characteristics (18 samples).

Parameter	Mean	Range	Std. Deviation
Flow (gpm)*	36.40	26.50-47.70	6.59
(gpT)	1193.	969-1564	218.
(gal/case)**	14.66	11.90-19.21	---
COD (lb/T)	13.71	7.94-19.08	3.85
BOD*** (lb/T)	7.40	4.29-10.30	---
Total Solids**** (lb/T)	13.25	6.58-18.15	3.76
Suspended Solids (lb/T)	0.36	0.13	0.18-0.65
Settleable Solids (ml/l)	3.4	0.0-8.0	2.9
Total Nitrogen***** (lb/T)	0.0400	0.0250-0.0590	---
NO_3^- (lb-N/T)	0.0110	0.0070-0.0160	0.0030
NO_2^- (lb-N/T)	0.0000	---	---
NH_3 (lb-N/T)	0.0000	---	---
Organic N (lb/T)	0.0290	0.0180-0.0430	0.0080
Total Phosphorus (lb/T)	0.0110	0.0060-0.0149	0.0030
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0063	0.0036-0.0089	0.0018
Inorganic P (lb/T)	0.0079	0.0050-0.0102	0.0018
Total Soluble P (lb/T)	0.0081	0.0056-0.0120	0.0022
pH	4.6	4.1-5.1	
Dissolved Oxygen (mg/l)	10.2	9.7-10.5	0.7
Temperature (°C)	14.9	13.5-16.0	1.0

*Four peelers operating.
**Calculated on a yield basis of 81.4 cases/ton (7).
***Calculated from COD using BOD/COD ratio of 0.54.
****Volatile solids = 92 percent.
*****Calculated by summing components.

Table 18. Bartlett Pear Mechanical (Contour) Peeler Effluent Characteristics (23 samples).

Parameter	Mean	Range	Std. Deviation
Flow (gpm)*	79.21	58.80-102.80	10.84
(gpT)	507.	386-668	82.7
(gal/case)**	6.23	4.74-8.21	---
COD (lb/T)	31.57	24.37-42.45	4.60
BOD*** (lb/T)	17.05	13.16-22.92	---
Total Solids **** (lb/T)	29.61	23.23-37.73	3.91
Suspended Solids (lb/T)	2.01	1.57-2.86	0.39
Settleable Solids (ml/l)	61.4	40.0-100.0	18.4
Total Nitrogen***** (lb/T)	0.1450	0.1170-0.1970	---
NO_3^- (lb-N/T)	0.0290	0.0200-0.0430	0.0060
NO_2^- (lb-N/T)	0.0000	---	---
NH_3 (lb-N/T)	0.0000	---	---
Organic N (lb/T)	0.1160	0.0970-0.1540	0.0180
Total Phosphorus (lb/T)	0.0190	0.0150-0.0230	0.0030
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0130	0.0060-0.0190	0.0026
Inorganic P (lb/T)	0.015	0.0120-0.0180	0.0020
Total Soluble P (lb/T)	0.017	0.0120-0.0200	0.0020
pH	4.2	3.9-4.5	0.2
Dissolved Oxygen (mg/l)	9.9	8.9-10.5	0.6
Temperature (°C)	15.4	13.5-17.5	0.9

*Water usage averaged about 4.5 gpm/peeler.
**Calculated on a yield basis of 81.4 cases/ton (7).
***Calculated from COD using BOD/COD ratio of 0.54.
****Volatile solids = 96 percent.
*****Calculated by summing components.

CONCLUSIONS

The foregoing, summarized on Figures 5 through 7, where means and ranges are depicted, has been only a summary of the findings of the first two seasons' work. Subsequent papers detailing each commodity will be published.

Among the general trends indicated by the above data are: 1) that some characteristics presently being reported in text and reference books may be obsolete and not representative of conditions in (an unknown number of) today's canneries; 2) that fruit processing wastewater characteristics vary distinctly with commodity and even, probably, with variety and that, therefore (as has often been done) the values for one commodity cannot justifiably be extrapolated from those for another; 3) that the

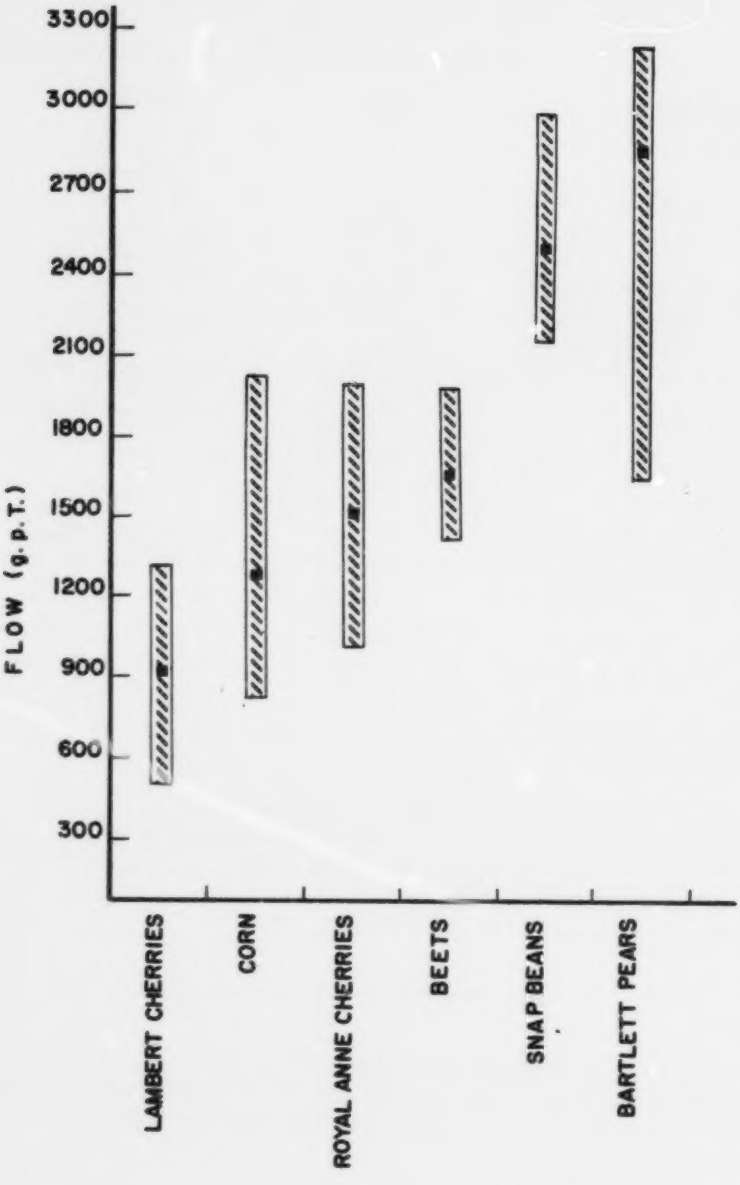


Figure 5. Wastewater Volume Summary

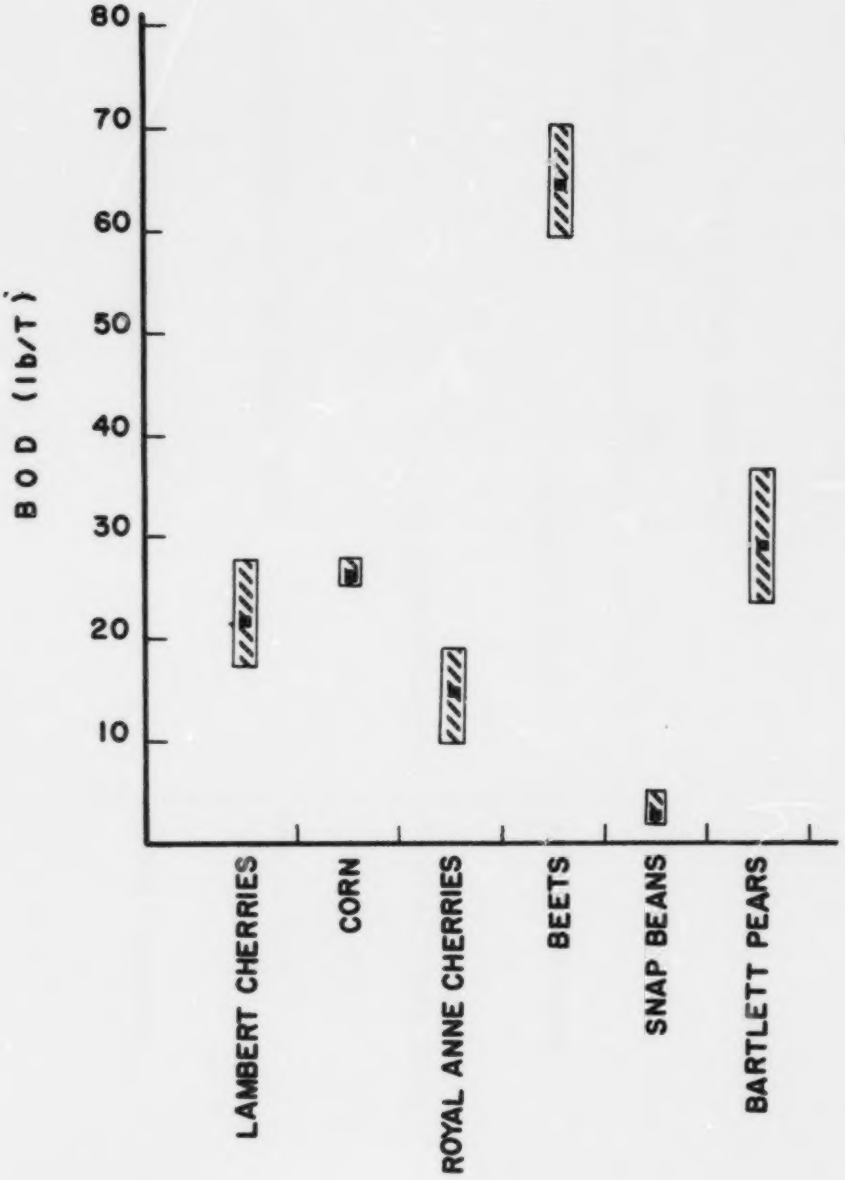


Figure 6. Biochemical Oxygen Demand Summary

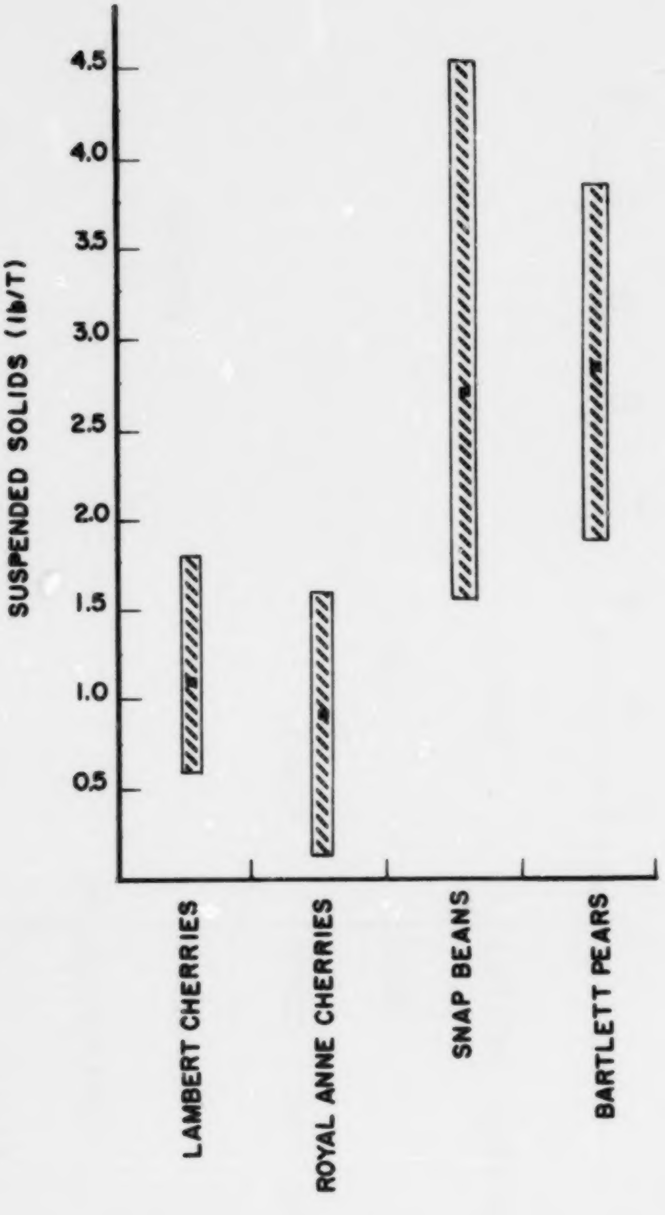


Figure 7. Suspended Solids Summary

greatest portion of the pollutant load generated in cherry processing occurs at a single source, the pitters, and that, perhaps, this waste stream should be incorporated into a by-product recovery system; and 4) that new designs for processing equipment should be evaluated in terms of waste generation, as well as the more production-oriented parameters.

The availability of reliable, contemporary wastewater characterization data (such as the foregoing) should facilitate the efficient, enlightened approaches to solving environmental problems now being demanded of industry and government by an aroused public.

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DISCLAIMER

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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PROGRESS REPORT: SEAFOODS PROCESSING WASTEWATER CHARACTERIZATION*

by

M. R. Soderquist**, G. I. Blanton, Jr.**, J. E. Borden** and
K. S. Hilderbrand**

INTRODUCTION

The Department of Food Science and Technology at Oregon State University is currently involved in a research project in which the effluents from seafoods processing plants are being monitored, sampled and analyzed. This work has evolved from two other Departmental projects: 1) a study of the current "state-of-the-art" of seafoods processing waste management,(1) and 2) a waste characterization study of the Oregon fruit and vegetable processing industry.(2) The study is being funded mainly by the Environmental Protection Agency and the National Canners Association.

In November, 1971, the Department's mobile laboratory(3) was located at the Oregon State University Seafoods Laboratory in Astoria, Oregon. From that base the wastes produced by roughly a dozen different seafoods plants were being monitored as they processed six seasonal commodities: Dungeness crab, bottom fish, shrimp, clams, tuna and salmon. In addition, the wastes generated in the production of by-products were being characterized.

Using methods outlined in a previous paper,(3) flow, temperature, dissolved oxygen and pH were monitored on-site and flow proportioned composite samples were subsequently analyzed for total-, dissolved-, volatile-, settleable- and suspended-solids, chemical oxygen demand (COD), five-day-(BOD) and ultimate-biochemical oxygen demand ($BOD_{ult.}$), oil and grease, nitrite, nitrate, organic nitrogen, ammonia, orthophosphate, total inorganic phosphorus, soluble phosphorus, total phosphorus, fecal coliform, total coliform and fecal streptococcus.

At this writing three months' Dungeness crab wastewater data have been gathered. This paper presents the results of that work.

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**Department of Food Science and Technology, Oregon State University, Corvallis, Oregon.

THE DUNGENESS CRAB PROCESS

Many factors influence the character and volumes of wastewaters discharged from a seafood (or any food) processing plant.(4) These include:

1) variability in raw product supply;
2) condition of raw product (e.g., maturity of animal and storage time in vessel);
3) species being processed (seafoods yields vary from 15 to 100 percent);
4) harvesting method;
5) degree of pre-processing, if any (Gulf of Mexico shrimp are often beheaded at sea, as is much of the Alaskan halibut catch);
6) manufacturing process;
7) form of finished product (canned prime fillet vs. fish paste, for instance);
8) location of plant (New England vs. Southern California; congested metropolitan area vs. remote, isolated site);
9) plant age;
10) maximum production capacity and specific operating level;
11) operating schedule (intermittant vs. continuous);
12) water supply availability and cost; and
13) waste treatment and/or disposal methods required and their costs.

Except for item (3) above, each of these variables is applicable to the Dungeness crab processing industry.

The Dungeness crab process is depicted schematically in Figure 1. Variations in this general scheme for specific plants will be pointed out as each plant's effluent is discussed. Three plants were monitored. The following process descriptions refer to those plants.

After delivery from the vessel the crabs, unless they were to be marketed whole, were first butchered. The backs were detached, the viscera removed and the legs separated from the bodies. Some plants flumed the solids from this process to a central screen, but most employed dry capture techniques. In the latter instance the only flows from the butchering area were clean-up waters.

The next unit operation was bleeding-rinsing. The crab pieces were either conveyed via belt below a water spray or were packed in large steel baskets and submerged in circulating rinsewater. In either case a continuous wastewater flow resulted.

The crab parts (and whole crab) were then cooked in boiling water. Whole crab were boiled in a 50,000-60,000 mg/l (as Cl-) sodium chloride solution containing 650-800 mg/l citric acid for 20 to 30 minutes.

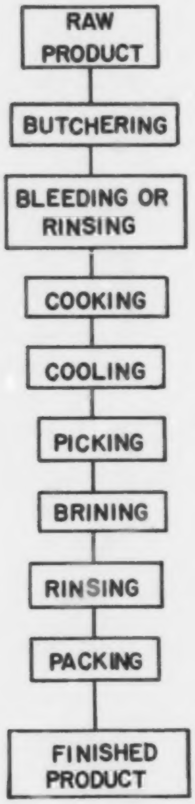
RAW PRODUCT
BUTCHERING
BLEEDING OR RINSING
COOKING
COOLING
PICKING
BRINING
RINSING
PACKING
FINISHED PRODUCT

Figure 1. The Dungeness crab process

Whereas the salt was used for seasoning, the citric acid facilitated shell cleaning (by loosening adhering material) in a subsequent step. Crab sections, on the other hand, were simply water boiled for twelve minutes or so. The wastewater flows from this step, of course, were intermittant, occuring whenever a cooker was "dumped."

As was bleeding-rinsing, the next step, cooling, was accomplished in two ways. The simpler method employed was to spray the hot crabs with water, resulting in a continuous wastewater flow. The more sophisticated plants employed immersion of the crab-filled baskets in tanks into which cooling water was constantly flowing. After twenty minutes the baskets were removed and allowed to drain. The resulting wastewaters consisted of a continuous flow (the cooling tank overflow) and discrete flows (cooling tank "dumps" plus crab basket drainage).

In all plants surveyed, "picking" of the meat from the shell was a manual operation. "Picking stock" included bodies and legs. Yields varied from 17 to 27 percent. This variation was mainly a function of the maturity of the animals; yields increased as the season progressed. No water was used in this unit operation except during wash-down.

The cleaned meat was conveyed to brine tanks where loose shell was separated from the meat by flotation. The 100,000 to 200,000 mg/l (as Cl^-) sodium chloride solutions were discharged intermittantly.

Most of the salt solution remaining on the meat was removed in the next unit operation, the (immersion) rinse tanks. The discharges from these tanks were continuous and contained 1500-2000 mg Cl^-/l.

After rinsing the meat was drained and packed. Whether packing in cardboard and plastic for the fresh market or canning the meat, this operation contributed little to the wastewater systems except clean-up flows.

In those instances where meat was canned, the final step was retorting; in those where fresh packing was practiced, the last step was refrigeration. Both processes used water, but neither appreciably contaminated it, so these flows were ignored.

WASTEWATER CHARACTERISTICS

Although three Dungeness crab processing plants were monitored regularly during the three-month period, heavy emphasis was placed on that plant considered most typical. From seven to fourteen full-shift flow-proportioned samples were collected from each operation. Sampling frequency was determined by regularity and uniformity of discharge; the more erratic units were sampled more frequently. The other two plants were sampled less frequently; data gathered from these plants demonstrated variability in wastewater strengths and flows from plant to plant.

Influence of plant size on wastewater values could not be reliably demonstrated in this study because the three plants had similar production capacities: from six to eight tons per shift. Further studies, however, may offer the opportunity to investigate the size vs. efficiency of utilization relationship.

Tables 1 through 11 refer to the plant most frequently monitored, designated Plant No. 1. The reader will note the absence of bacteriological data. This is because that phase of the study, being independently funded (by the National Canners Association), was begun several months after the initiation of the "parent" EPA-funded project. These data were not in final form at this writing.

Table 1 reveals the nature of the combined wastewater stream, both with and without the contribution of the whole crab processing line. A typical plant would handle both picking stock and whole crab, but the bulk of the process would be devoted to picking stock. The dual presentation should allow a plant engineer or a wastewater treatment plant designer to consider the influence of either system alone. On this table standard deviations are not listed because the values listed represent summations of means, maxima and minima from the sub-processes.

It may be of interest to compare Dungeness crab processing wastewater strengths with those of other food processing operations. The O.S.U. fruit and vegetable study(2) concluded that green bean processing generates about 7 lb COD/ton of raw product. Other values presented included Royal Anne cherries, 28 lb/T; sweet corn, 34 lb/T; Lambert cherries, 37 lb/T; Bartlett pears, 55 lb/T; and red beets, 75 lb/T. By comparison, then, the Dungeness crab plant no. 1, at 22 lb COD/T, falls below most fruits and vegetables characterized to date. The values for plants numbers 2 and 3 will be found in the Appendix. Plant no. 2 (Table 12) produced nearly identical COD loadings, whereas Plant no. 3 (Table 22) generated half again as much. The latter plant, however, was operating a temporary processing line while its main facilities were being remodeled. This may have led to the higher wastewater loadings, reflecting lower yields caused by less-than-optimum processing conditions.

Water consumption figures, on the other hand, present a different picture. The range for fruits and vegetables in the above-mentioned study(2) was 900-2900 gal/T. Water use in Dungeness crab plant no. 1 was about 3600 gal/T. Reference to the Appendix indicates that water consumption in plant no. 2 (Table 12) was about 5100 gal/T (excluding shell flume) and in plant no. 3 (Table 22), about 5011 gal/T (excluding butchering flume). The authors doubt that Dungeness crab processing inherently requires more than twice the water used in the average fruit and vegetable processing plant. It therefore seems likely that a water conservation program would effect significant cost savings (in terms of lowered water bills only--since few, if any, crab plants now pay flow-based sewerage fees) in the average crab plant.

Perhaps the most striking difference between fruit and vegetable processing wastes and Dungeness crab wastewaters is the nutrient (nitrogen and phosphorus) content. The crab wastewater level of both nutrients was an order of magnitude greater than those values of the previous study(2). Organic nitrogen levels, especially, were high. Concentrations of 1500 mg organic N/l were not uncommon.

For satisfactory biological waste treatment, a minimal BOD:N:P ratio is said to be about 150:5:1(5). From Table 1, the BOD:N:P ratio of 43:4.4:1 can be calculated. This indicates that sufficient nitrogen

Table 1. Combined Wastewater Characteristics Plant No. 1

Parameter	Picking Stock Only Mean	Picking Stock Only Range	Picking Stock & Whole Crabs Mean	Picking Stock & Whole Crabs Range
Flow (gpm)*	30.[illegible]	---	32.93	---
(gpT)	3564.85	---	3840.1	---
COD (lb/T)	22.23	14.65-31.11	33.90	23.05-45.72
BOD** (lb/T)	13.16	8.64-18.35	20.00	13.600-26.975
Total Solids (lb/T)	171.86	98.70-248.06	200.56	221.7-890.06
Settleable Solids (ml/l)	92.4	39.55-149.7	93.7	39.65-152.2
Suspended Solids (lb/T)	5.33	2.59-8.392	6.62	3.47-9.96
Volatile Solids (%)	34.2	24.2-43.6	35.5	24.8-47.0
Total Nitrogen*** (lb/T)	3.010	2.049-4.231	4.2972	3.0611-6.1460
NO$_3^-$ (lb-N/T)	0.0073	0.0045-0.0122	0.0076	0.00459-0.01265
NO$_2^-$ (lb-N/T)	0.00036	0.00027-0.00111	0.00042	0.0003-0.001222
NH$_3$ (lb-N/T)	0.1889	0.1213-0.2818	0.3562	0.2572-0.4781
Organic N (lb/T)	2.814	1.[illegible]128	3.933	2.799-5.654
Total Phosphorus (lb/T)	0.3053	0.[illegible].5512	0.372	0.1653-0.654
Ortho-PO$_4^{\equiv}$ (lb-P/T)	0.1432	0.0557-0.2893	0.1645	0.0625-0.3238
Inorganic P (lb/T)	0.1958	0.0821-0.3306	0.2307	0.0978-0.3866
Total Soluble P (lb/T)	0.2502	0.0979-0.4650	0.3042	0.1272-0.5445
pH	7.3	7.1-8.5	7.3	7.1-8.5
Dissolved Oxygen (mg/l)	11.06	10.56-12.02	11.06	10.56-12.02
Temperature (°C)	9.4	6.91-13.46	9.4	6.91-13.46

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*Σ water volumes discharged/Σ operating times on days when system was monitored.

**Calculated from COD using BOD/COD = 0.59.

***Calculated by summing components.

Table 2. Butchering Area Clean-up Wastewater Characteristics Plant No. 1 (7 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	29.81	---	---	---
(gpT)	336.3	185.1-498.7	128.9	9.43
COD (lb/T)	2.67	1.22-4.78	1.50	12.01
BOD** (lb/T)	1.575	0.720-2.82	---	11.97
Total Solids (lb/T)	3.77	1.05-8.22	3.05	2.19
Settleable Solids (ml/l)	3.6	1.7-7.5	2.0	---
Suspended Solids (lb/T)	0.59	0.153-1.07	0.30	11.06
Volatile Solids (%)	48.47	44.0-52.85	3.45	---
Total Nitrogen*** (lb/T)	0.2731	0.0993-0.5163	---	9.07
NO_3^- (lb-N/T)	0.0008	0.0005-0.0011	0.0002	10.96
NO_2^- (lb-N/T)	0.00004	0.00002-0.00070	0.00004	11.11
NH_3 (lb-N/T)	0.0153	0.0058-0.0275	0.0091	8.10
Organic N (lb/T)	0.257	0.093-0.487	0.171	9.13
Total Phosphorus (lb/T)	0.0210	0.0092-0.0395	0.013	6.88
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0088	0.0029-0.0183	0.0068	6.15
Inorganic P (lb/T)	0.0137	0.0058-0.0249	0.0086	7.00
Total Soluble P (lb/T)	0.0148	0.0058-0.0283	0.0104	5.92
pH	7.5	7.4-7.6	---	---
Dissolved Oxygen (mg/l)	11.87	---	0.35	---
Temperature (°C)	8.2	---	2.2	---

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*Σ water volumes discharged/Σ operating times on days when area was sampled.

**Calculated from COD using BOD/COD = 0.59.

***Calculated by summing components.

Table 3. Bleeding Tank Overflow Characteristics Plant No. 1 (5 samples)

Parameter	Mean	Range	Standard Deviation	% of Bleeding Tank Total	% of Plant Total
Flow (gpm)*	7.96	---	---	---	---
(gpT)	435.6	299.2-610.9	147.07	80.65	12.5
COD (lb/T)	2.21	2.04-2.37	0.14	76.47	9.94
BOD** (lb/T)	1.30	1.20-1.40	---	76.47	9.88
Total Solids (lb/T)	3.45	2.87-3.77	0.40	80.61	2.01
Settleable Solids (ml/l)	0.5	0.1-0.8	0.4	---	---
Suspended Solids (lb/T)	0.29	0.12-0.50	0.17	76.32	0.05
Volatile Solids (%)	49.34	44.75-57.15	5.25	---	---
Total Nitrogen*** (lb/T)	0.24077	0.21992-0.27134	---	73.71	32.44
NO_3^- (lb-N/T)	0.00053	0.00038-0.00084	0.00027	66.25	7.26
NO_2^- (lb-N/T)	0.00004	---	---	66.67	11.11
NH_3 (lb-N/T)	0.0112	0.0085-0.0155	0.0038	75.68	5.93
Organic N (lb/T)	0.229	0.211-0.255	0.023	73.63	8.14
Total Phosphorus (lb/T)	0.0151	0.0101-0.0228	0.0068	81.75	4.95
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0045	0.0039-0.0051	0.0005	71.43	3.14
Inorganic P (lb/T)	0.0060	0.0055-0.0069	0.0008	71.43	3.06
Total Soluble P (lb/T)	0.011	0.0086-0.014	0.0028	72.85	4.52
pH	7.3	6.8-7.7	---	---	---
Dissolved Oxygen (mg/l)	11.5	---	0.33	---	---
Temperature (°C)	6.9	---	1.4	---	---

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*Σ water volumes discharged/Σ operating times on days when unit was sampled.

**Calculated from COD using BOD/COD = 0.59.

***Calculated by summing components.

Table 4. Bleeding Tank Discrete Discharge Characteristics Plant No. 1 (5 samples)

Parameter	Mean	Range	Standard Deviation	% of Bleeding Tank Total	% of Plant Total
Flow (gpm)*	1.69	---	---	---	---
(gpT)	105.5	58.9-371.5	---	19.35	2.96
COD (lb/T)	0.68	0.37-1.10	0.38	32.53	3.06
BOD** (lb/T)	0.40	0.22-0.65	---	23.53	3.04
Total Solids (lb/T)	0.83	0.28-1.68	0.75	19.39	0.48
Settleable Solids (ml/l)	0.7	0.3-1.3	0.5	---	---
Suspended Solids (lb/T)	0.09	0.038-0.112	0.035	23.68	5.44
Volatile Solids (%)	47.79	46.0-50.8	2.28	---	---
Total Nitrogen*** (lb/T)	0.08589	0.06002-0.12640	---	26.29	14.07
NO_3^- (lb-N/T)	0.00027	0.00021-0.00032	0.00006	33.75	3.69
NO_2^- (lb-N/T)	0.00002	0.00002-0.00003	0.00001	33.33	5.56
NH_3 (lb-N/T)	0.0036	0.0018-0.0051	0.0016	24.32	1.91
Organic N (lb/T)	0.082	0.058-0.121	0.029	26.37	2.91
Total Phosphorus (lb/T)	0.0036	0.0015-0.0071	0.0031	19.25	1.18
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0018	0.0003-0.0028	0.0013	28.57	1.26
Inorganic P (lb/T)	0.0024	0.0005-0.0037	0.0017	28.57	1.23
Total Soluble P (lb/T)	0.0041	0.0015-0.0066	0.0036	27.15	1.64
pH	7.1	7.0-7.3	---	---	---
Dissolved Oxygen (mg/l)	11.45	---	0.35	---	---
Temperature (°C)	7.2	---	1.5	---	---

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*Σ water volumes discharged/Σ operating times on days when unit was sampled.

**Calculated from COD using BOD/COD = 0.59.

***Calculated by summing components.

Table 5. Section Cooker Wastewater Characteristics Plant No. 1 (11 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	1.40	---	---	---
(gpT)	87.92	50.37-385.05	---	2.46
COD (lb/T)	5.40	4.01-6.55	1.02	24.29
BOD** (lb/T)	3.78	2.81-4.59	---	28.72
Total Solids (lb/T)	9.31	7.06-13.57	2.23	5.41
Settleable Solids (ml/l)	1.7	0.5-4.0	1.1	---
Suspended Solids (lb/T)	1.14	0.606-1.928	0.458	21.38
Volatile Solids (%)	55.49	46.0-60.35	5.69	---
Total Nitrogen*** (lb/T)	0.77241	0.63256-0.95586	---	25.65
NO_3^- (lb-N/T)	0.00010	0.00005-0.00025	0.00007	1.37
NO_2^- (lb-N/T)	0.00001	0.000011-0.000014	0.000002	2.78
NH_3 (lb-N/T)	0.0813	0.0545-0.1140	0.0223	43.04
Organic N (lb/T)	0.691	0.578-0.842	0.103	24.56
Total Phosphorus (lb/T)	0.0448	0.0202-0.0603	0.0159	14.67
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0097	0.0035-0.0144	0.0043	6.77
Inorganic P (lb/T)	0.0242	0.0183-0.0336	0.0063	12.36
Total Soluble P (lb/T)	0.0304	0.0185-0.0411	0.0089	12.15
pH	8.5	8.4-8.6	---	---
Dissolved Oxygen (mg/l)	---	---	---	---
Temperature (°C)	---	---	---	---

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*Σ water volumes discharged/Σ operating times on days when unit was sampled.

**Calculated from COD using BOD/COD = 0.70.

***Calculated by summing components.

Table 6. Whole Crab Cooker Wastewater Characteristics Plant No. 1 (8 samples)

Parameter	Mean	Range	Standard Deviation
Flow (gpm)*	0.747	---	---
(gpT)	275.2	129.2-877.3	---
COD (lb/T)	11.67	8.40-14.61	2.09
BOD** ((lb/T)	6.42	4.62-8.04	---
Total Solids (lb/T)	287	123-642	176
Settleable Solids (ml/l)	1.3	0.1-2.5	.8
Suspended Solids (lb/T)	1.29	0.890-1-570	0.261
Volatile Solids (%)	13.29	5.65-33.9	9.37
Total Nitrogen*** (lb/T)	1.28666	1.01202-1.72286	---
NO_3^- (lb-N/T)	0.00030	0.00009-0.00045	0.00015
NO_2^- (lb-N/T)	0.00006	0.000032-0.00011	0.00004
NH_3 (lb-N/T)	0.1673	0.1359-0.1963	0.0235
Organic N (lb/T)	1.119	0.876-1.526	0.225
Total Phosphorus (lb/T)	0.0671	0.0374-0.1028	0.0224
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0213	0.0068-0.0345	0.0105
Inorganic P (lb/T)	0.0349	0.0157-0.0560	0.0138
Total Soluble P (lb/T)	0.0540	0.0293-0.0795	0.0179
pH	7.5	6.1-8.2	---
Dissolved Oxygen (mg/l)	---	---	---
Temperature (°C)	---	---	---

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*Σ water volumes discharged/Σ operating times on days when unit was sampled.

**Calculated from COD using BOD/COD = 0.55.

***Calculated by summing components.

Table 7. Cooling Tank Overflow Characteristics Plant No. 1 (4 samples)

Parameter	Mean	Range	Standard Deviation	% of Cooling Tank Total	% of Plant Total
Flow (gpm)*	21.87	---	---	---	---
(gpT)	1067.45	1022.2-1215.6	123.41	90.31	29.94
COD (lb/T)	1.42	1.20-1.63	0.21	95.30	6.39
BOD** (lb/T)	0.71	0.60-0.815	---	95.30	5.40
Total Solids (lb/T)	3.18	2.64-3.71	0.75	79.10	1.85
Settleable Solids (ml/l)	0.2	0.05-0.6	0.2	---	---
Suspended Solids (lb/T)	0.20	0.116-0.309	0.093	58.82	3.75
Volatile Solids (%)	32.4	20.3-46.9	11.3	---	---
Total Nitrogen*** (lb/T)	0.1545	0.1188-0.1863	---	95.37	5.13
NO_3^- (lb-N/T)	0.0026	0.0021-0.0030	0.0005	92.86	35.62
$NO_2^=$ (lb-N/T)	0.0001	---	---	93.46	27.78
NH_3 (lb-N/T)	0.0178	0.0167-0.0193	0.0013	93.20	9.42
Organic N (lb/T)	0.134	0.100-0.164	0.032	95.71	4.76
Total Phosphorus (lb/T)	0.0216	0.0195-0.0230	0.0019	94.32	7.08
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0101	0.0082-0.0113	0.0016	96.19	7.05
Inorganic P (lb/T)	0.0111	0.0085-0.0134	0.0025	95.69	5.67
Total Soluble P (lb/T)	0.0163	0.0115-0.0213	0.0049	96.45	6.51
pH	7.2	7.1-7.6	---	---	---
Dissolved Oxygen (mg/l)	10.56	---	0.1808	---	---
Temperature (°C)	13.5	---	1.9	---	---

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*Σ water volumes discharged/Σ operating times on days when unit was sampled.

**Calculated from COD using BOD/COD = 0.50.

***Calculated by summing components.

Table 8. Cooling Tank Discrete Discharge Characteristics Plant No. 1 (5 samples)

Parameter	Mean	Range	Standard Deviation	% of Cooling Tank Total	% of Plant Total
Flow (gpm)*	1.14	---	---	---	---
(gpT)	114.5	66.1-524.3	---	9.69	3.21
COD (lb/T)	0.07	0.03-0.12	0.04	4.70	0.31
BOD** (lb/T)	0.03	0.015-0.06	---	4.70	0.27
Total Solids (lb/T)	0.84	0.25-1.36	0.56	20.90	0.48
Settleable Solids (ml/l)	0.4	---	0.2	---	---
Suspended Solids (lb/T)	0.14	0.007-0.023	0.007	41.18	2.62
Volatile Solids (%)	27.05	12.85-52.5	22.09	---	---
Total Nitrogen*** (lb/T)	0.0075	.0032-0.0129	---	4.63	0.25
NO_3^- (lb-N/T)	0.00020	0.00010-00030	0.00010	7.14	2.74
NO_2^- (lb-N/T)	0.000007	0.000006-0.000008	0.000001	6.54	1.94
NH_3 (lb-N/T)	0.0013	0.0011-0.0016	0.0002	6.80	0.69
Organic N (lb/T)	0.006	0.002-0.011	0.004	4.29	0.21
Total Phosphorus (lb/T)	0.0013	0.0005-0.0024	0.0010	5.68	0.43
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0004	0.0001-0.0006	0.0003	3.81	0.28
Inorganic P (lb/T)	0.0005	0.0004-0.0007	0.0002	4.31	0.26
Total Soluble P (lb/T)	0.0006	0.0004-0.0009	0.0003	3.55	0.24
pH	7.1	6.9-7.5	---	---	---
Dissolved Oxygen (mg/l)	11.25	---	1.20	---	---
Temperature (°C)	12.5	---	2.3	---	---

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*Σ water volumes discharged/Σ operating times on days when unit was sampled.

**Calculated from COD using BOD/COD = 0.50.

***Calculated by summing components.

Table 9. Picking Area Clean-up Flow Characteristics Plant No. 1 (8 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	27.48	---	---	---
(gpT)	285.02	51.8-923.0	277.94	7.99
COD (lb/T)	0.79	0.21-1.44	0.55	3.55
BOD** (lb/T)	0.44	0.12-0.81	---	5.34
Total Solids (lb/T)	1.72	0.29-4.19	1.49	1.00
Settleable Solids (ml/l)	6.3	3.8-13.0	3.3	---
Suspended Solids (lb/T)	0.37	0.165-0.681	0.17	6.94
Volatile Solids (%)	52.09	13.64-67.55	17.51	---
Total Nitrogen*** (lb/T)	0.0917	0.0147-0.1982	---	3.05
NO_3^- (lb-N/T)	0.003	0.00011-0.00062	0.00024	4.11
NO_2^- (lb-N/T)	0.00001	0.000008-0.00001	0.000001	2.76
NH_3 (lb-N/T)	0.0064	0.0016-0.0136	0.0049	3.39
Organic N (lb/T)	0.085	0.013-0.184	0.073	3.02
Total Phosphorus (lb/T)	0.0141	0.0039-0.0300	0.0115	4.62
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0078	0.0021-0.0144	0.0054	5.45
Inorganic P (lb/T)	0.0094	0.0023-0.0174	0.0070	4.80
Total Soluble P (lb/T)	0.0104	0.0022-0.0204	0.0083	4.16
pH	8.3	7.3-8.7	---	---
Dissolved Oxygen (mg/l)	11.14	---	0.56	---
Temperature (°C)	8.7	---	1.4	---

---

*Σ water volumes discharged/Σ operating times on days when area was sampled.

**Calculated from COD using BOD/COD = 0.56.

***Calculated by summing components.

Table 10. Brine Tank Discharge Characteristics Plant No. 1 (14 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	0.75	---	---	---
(gpT)	70.6	22.9-107.6	---	1.98
COD (lb/T)	6.00	3.57-8.11	1.42	26.99
BOD** (lb/T)	3.18	1.89-4.30	---	24.16
Total Solids (lb/T)	129.91	70.93-184.12	33.88	75.59
Settleable Solids (ml/l)	76.7	35-120	25.2	---
Suspended Solids (lb/T)	1.99	1.015-3.034	0.66	37.34
Volatile Solids (%)	15.11	4.8-31.35	9.12	---
Total Nitrogen*** (lb/T)	0.9705	0.6321-1.4011	---	32.24
NO_3^- (lb-N/T)	0.00005	0.00000-0.00009	0.00003	0.68
NO_2^- (lb-N/T)	0.00002	0.00000-0.00003	0.00001	5.56
NH_3 (lb-N/T)	0.0335	0.0221-0.0450	0.0073	17.73
Organic N (lb/T)	0.937	0.610-1.356	0.222	33.30
Total Phosphorus (lb/T)	0.1217	0.0290-0.2403	0.0676	39.86
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0573	0.0084-0.1400	0.0408	40.01
Inorganic P (lb/T)	0.0813	0.0155-0.1408	0.0636	41.52
Total Soluble P (lb/T)	0.1034	0.0181-0.2064	0.0616	41.33
pH	7.4	7.0-8.1	---	---
Dissolved Oxygen (mg/l)	11.19	---	0.69	---
Temperature (°C)	9.7	---	1.8	---

---

*Σ water volumes discharged/Σ operating times on days when unit was sampled.

**Calculated from COD using BOD/COD = 0.53.

***Calculated by summing components.

Table 11. Rinse Tank Overflow Characteristics Plant No. 1 (10 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	10.96	---	---	---
(gpT)	1061.9	708.8-2742.4	325.5	29.79
COD (lb/T)	2.99	2.00-5.01	0.90	13.45
BOD** (lb/T)	2.15	1.44-3.61	---	16.34
Total Solids (lb/T)	18.85	13.33-27.44	5.05	10.96
Settleable Solids (ml/l)	1.0	0.5-2.0	0.513	---
Suspended Solids (lb/T)	0.52	0.359-0.732	0.12	9.76
Volatile Solids (%)	13.76	9.65-17.00	2.64	---
Total Nitrogen*** (lb/T)	0.4140	0.2682-0.7544	---	13.75
NO_3^- (lb-N/T)	0.0024	0.0010-0.0057	0.0012	32.88
NO_2^- (lb-N/T)	0.00011	0.00007-0.00018	0.00006	30.56
NH_3 (lb-N/T)	0.0185	0.0092-0.0406	0.0102	9.79
Organic N (lb/T)	0.393	0.258-0.708	0.111	13.97
Total Phosphorus (lb/T)	0.0621	0.0340-0.1258	0.0242	20.34
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0428	0.0263-0.0824	0.0148	29.89
Inorganic P (lb/T)	0.0472	0.0253-0.0892	0.0180	24.11
Total Soluble P (lb/T)	0.0589	0.0313-0.1258	0.0236	23.54
pH	7.2	6.9-7.9	---	---
Dissolved Oxygen (mg/l)	12.02	---	0.23	---
Temperature (°C)	7.6	---	1.3	---

---

*Σ water volumes sampled/Σ operating times on days when unit was sampled.

**Calculated from COD using BOD/COD = 0.72.

***Calculated by summing components.

and phosphorus were available for effective biological treatment.

The discussion of water consumption, above, deliberately excluded two solid waste fluming systems, the shell flume of plant no. 2 and the butchering flume of plant no. 3. This was done because the authors believe such large water users to be vestiges of earlier days and not representative of the majority of today's modern plants nor, certainly, those of the future.

Except for those plants which flume their butchering waste (a practice not recommended), the only wastewater flow from the butchering area is wash-down water. As shown on Table 2, only about ten percent or less of the total for each parameter was generated in this area.

Two tables appear for the bleeding area. This is because two waste streams originated there in plant no. 1. The first was the overflow from the rinse tank (Table 3); the second, the once-per-shift purging of the tank ("dump"--Table 4). Although 13 percent of the total plant COD was generated there (overflow plus dump), the process was not a major waste source.

The cookers were the second-most-important waste source. Table 5 presents data from the section cooker and Table 6, the data from the whole cooker. The whole cooker used more water per ton of crab and generated much more COD on a tonnage basis. These values (Table 6) are misleading, however, because the whole cooker throughput was much lower than that of the section cooker. Since cooking water COD concentration was a function of crab throughput and since dumping schedules were fairly constant, it is not surprising that the whole cooker COD level (on a production basis) appears to be so much higher than its section cooker counterpart.

Ignoring, temporarily, the contributions from the whole cooker for reasons discussed above, one notes (Table 5) that the section cooker was the major source of ammonia and the "number two" source of COD, suspended solids and total nitrogen in plant no. 1. Inspection of Tables 15 and 25 in the Appendix indicates general agreement with this finding. All samples, incidently, were pre-screened at 20 mesh prior to analysis.

The tremendous whole cooker total solids level indicated on Table 6 was due mainly to the NaCl added to the unit, as was discussed in "The Dungeness Crab Process" section. The fact that only 1.3 lb/T of 287 lb/T total solids were retainable on glass fiber filters supports this contention.

The cooling tank (Tables 7 and 8) was a major water user (30%) but contributed little to the total COD, solids or nutrient loads.

Likewise the picking area clean-up waters (Table 9) were not major offenders.

The major offender in the Dungeness crab plant, in terms of water pollution potential, was the brining step. The brine tank discharge of plant no. 1 (Table 10) was the major contributor of COD, total solids (mainly salt), suspended solids (after 20-mesh screening), total nitrogen and total phosphorus. With the initial samples the high salt level (particularly chloride) in the brine created interferences with some of the tests, but these were soon overcome and the program successfully conducted. Mercuric sulfate was used to counteract chloride interference in the COD analysis.

The influence of the brine tank was reflected in the brine rinsewater characteristics (Table 11). Total phosphorus was especially high, being second only to the brine, itself.

CONCLUSIONS

The results of this study (plant no. 1 only) are summarized on Figures 2 through 6.

Based on the data from the three plants monitored, it appears that the process-by-process breakdown of wastewater flows and constituents is fairly consistent from plant-to-plant, at least within the production range studied (0-10 tons/shift).

Some plants flume solid wastes. This is not necessary. Almost invariably they screen the flume water prior to discharge. Replacement of flumes with dry capture systems would significantly reduce the total plant waste load and is strongly recommended.

In the processing of Dungeness crab the major waste contributors are the cooking and brining operations. At some time in the future segregation and separate treatment of these streams may be advisable. Furthermore, alternatives to brining may be available(6). Elimination of the brining step would greatly reduce the pollutional impact of the industry.

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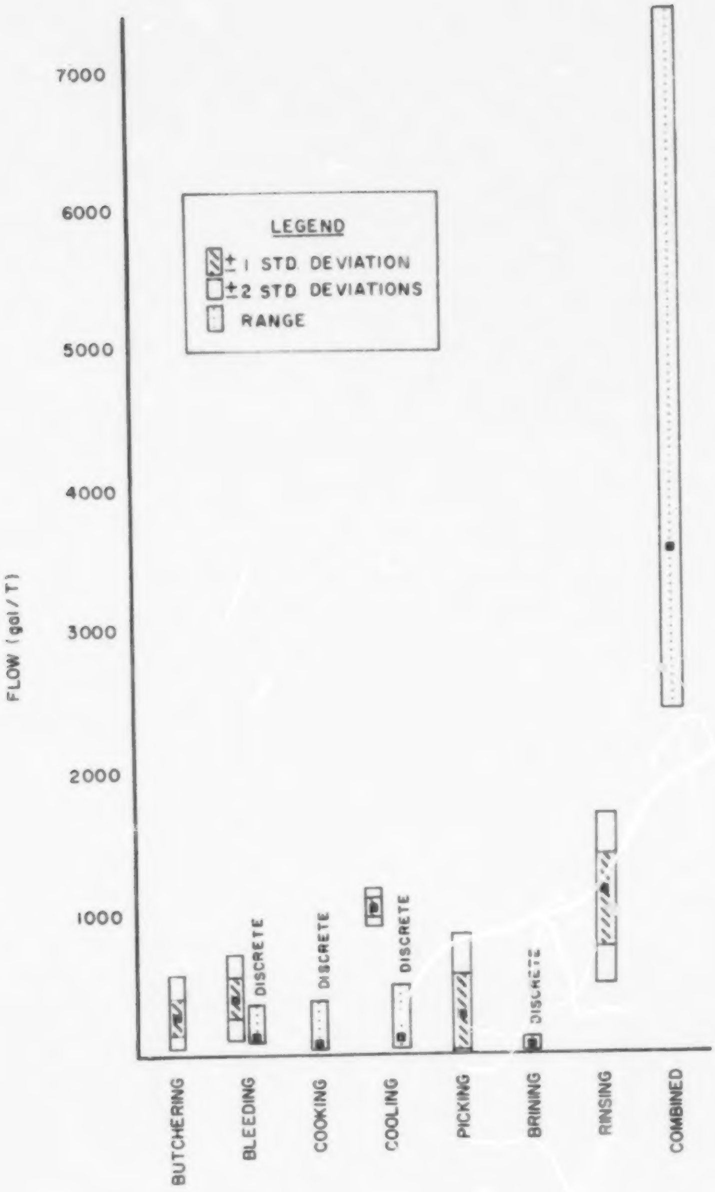

Figure 2. Wastewater Volume Summary

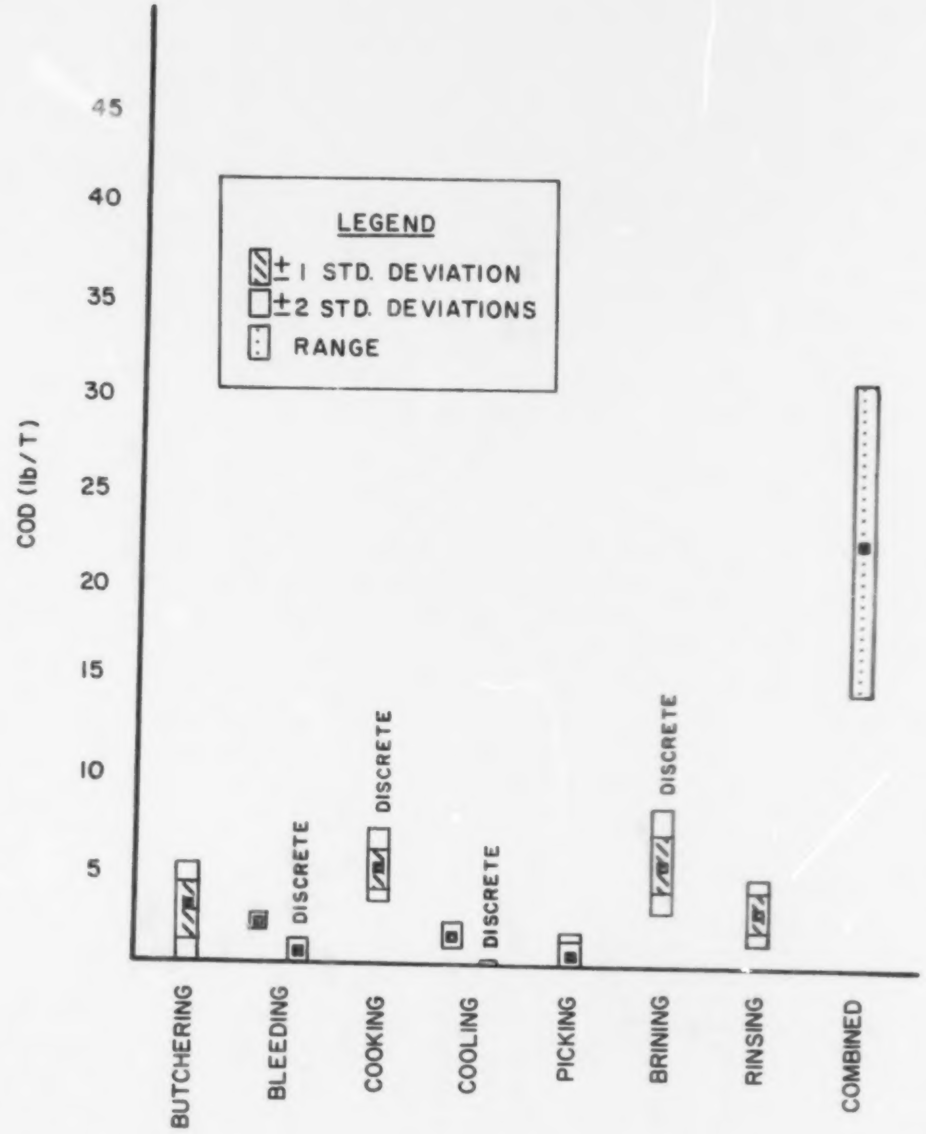

Figure 3. Chemical Oxygen Demand Summary

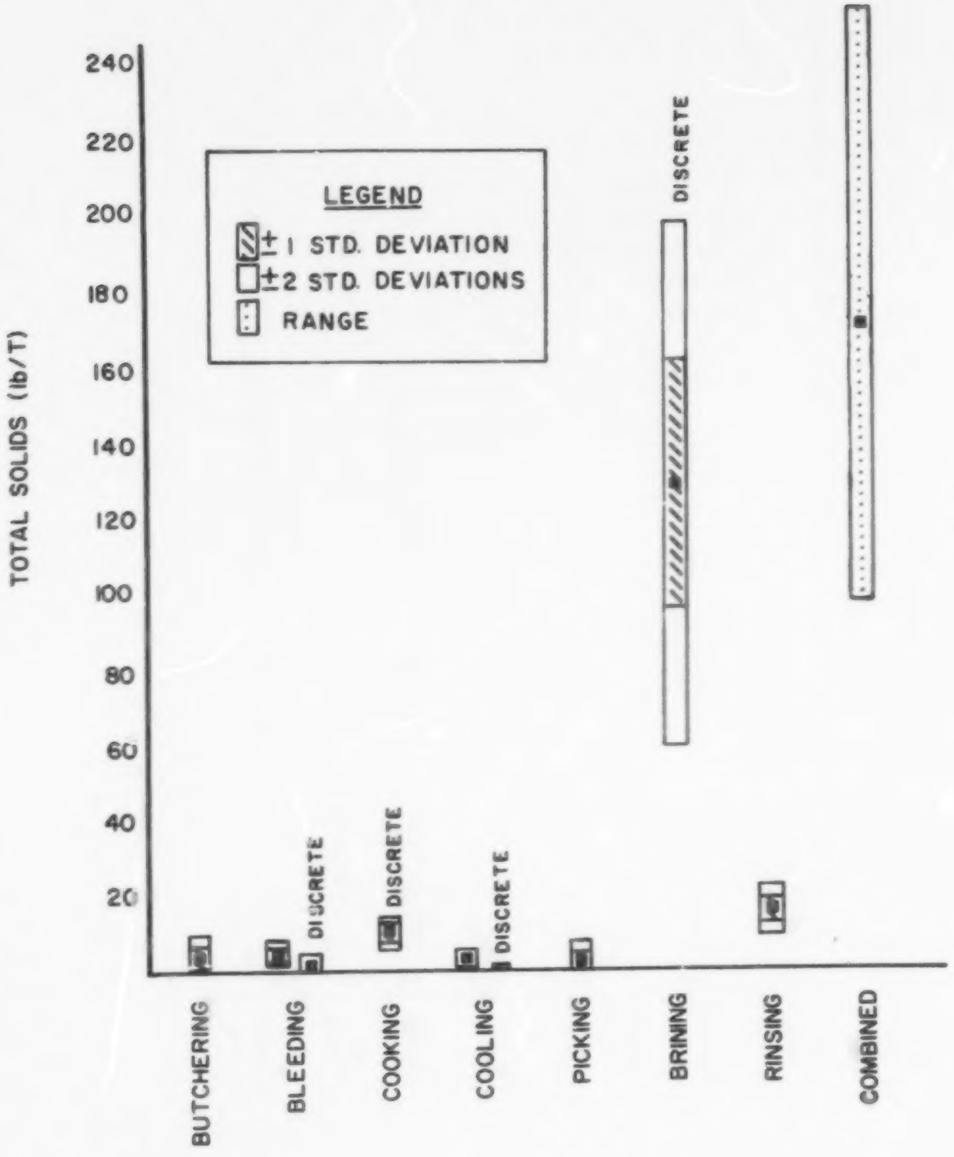

Figure 4. Total Solids Summary

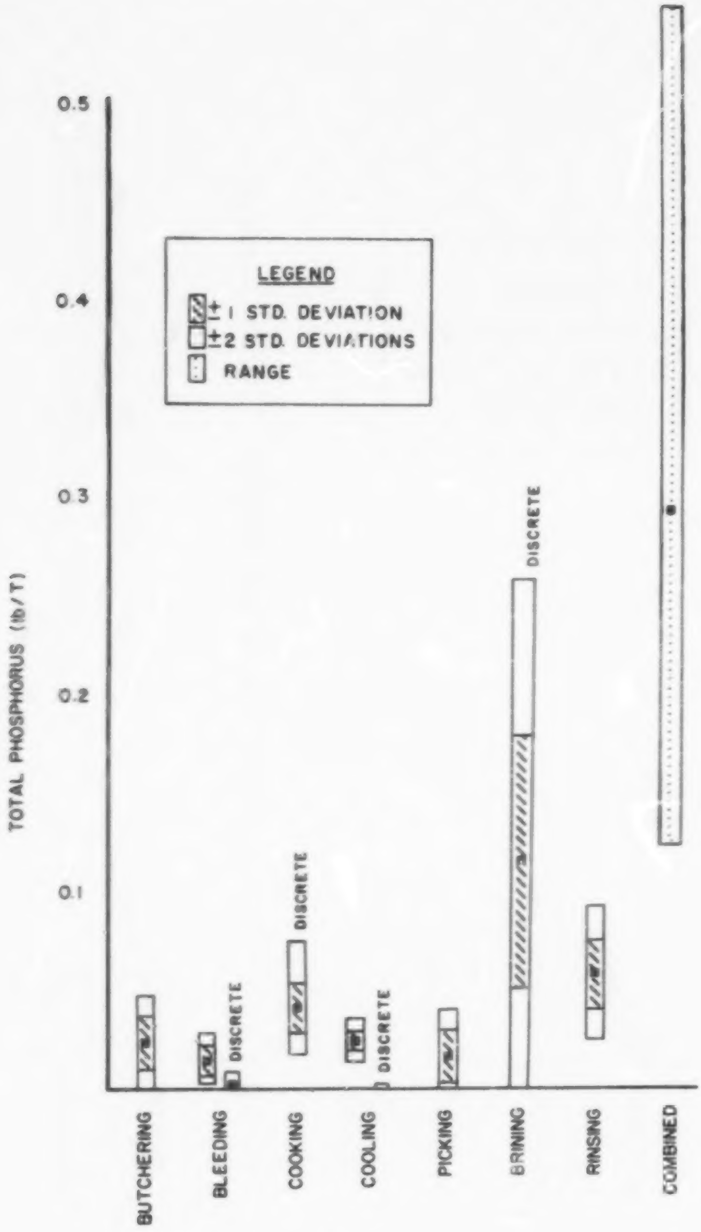

Figure 5. Total Phosphorus Summary

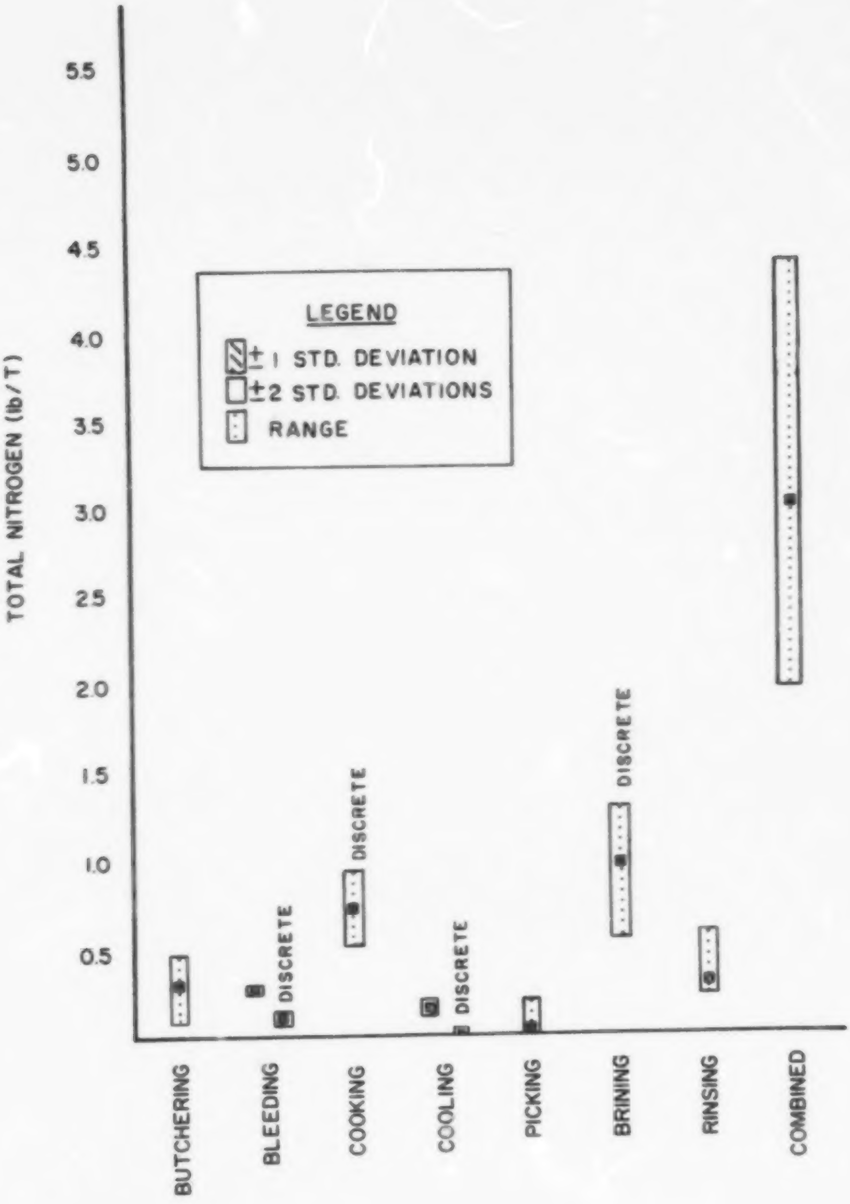

Figure 6. Total Nitrogen Summary

APPENDIX

Table 12. Combined Wastewater Characteristics Plant No. 2

Parameter	Without Shell Flume		With Shell Flume	
	Mean	Range	Mean	Range
Flow (gpm)*	---	---	---	---
(gpT)	5100.39	---	9126.36	---
COD (lb/T)	22.08	---	27.16	---
BOD** (lb/T)	13.916	---	17.316	---
Total Solids (lb/T)	286.45	---	295.95	---
Settleable Solids (ml/l)	92.07	---	92.37	---
Suspended Solids (lb/T)	5.11	---	6.17	---
Volatile Solids (%)	59.9	---	65.6	---
Total Nitrogen*** (lb/T)	3.04619	---	3.58958	---
NO_3^- (lb-N/T)	0.00962	---	0.01802	---
NO_2^- (lb-N/T)	0.000077	---	0.000077	---
NH_3 (lb-N/T)	0.1507	---	0.1798	---
Organic N (lb/T)	2.8858	---	3.5535	---
Total Phosphorus (lb/T)	0.3774	---	0.4996	---
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.1845	---	0.2474	---
Inorganic P (lb/T)	0.2474	---	0.3187	---
Total Soluble P (lb/T)	0.2948	---	0.3903	---
pH	7.3	6.9-8.7	7.3	---
Dissolved Oxygen (mg/l)	10.2	11.23-12.37	---	---
Temperature (°C)	5.72	4.27-8.30	---	---

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*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.61.

***Calculated by summing components.

Table 13. Butchering: Cooking Area Washwater Characteristics Plant No. 2 (1 sample)

Parameter	Mean	% of Plant Total
Flow (gpm)*	37.0 (0.583 hr)	---
(gpT)	225.09	4.41
COD (lb/T)	0.79	3.58
BOD** (lb/T)	0.466	3.35
Total Solids (lb/T)	1.11	0.39
Settleable Solids (ml/l)	2.5	---
Suspended Solids (lb/T)	0.31	6.10
Volatile Solids (%)	66.4	11.09
Total Nitrogen*** (lb/T)	0.07820	2.57
NO_3^- (lb-N/T)	0.0005	5.20
NO_2^- (lb-N/T)	0.0000	0.00
NH_3 (lb-N/T)	0.0000	0.00
Organic N (lb/T)	0.0777	2.69
Total Phosporus (lb/T)	0.0141	3.74
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0083	4.50
Inorganic P (lb/T)	0.0094	3.80
Total Soluble P (lb/T)	0.0113	3.83
pH	7.6	---
Dissolved Oxygen (mg/l)	12.2	---
Temperature (°C)	4.5	---

---

*Total volume/total time during periods when operation was sampled.
**Calculated from COD using BOC/COD = 0.59.
***Calculated by summing components.

Table 14. Preliminary Rinsing and Bleeding Wastewater Characteristics Plant No. 2 (1 sample)

Parameter	Mean	% of Plant Total
Flow (gpm)*	20.2	---
(gpT)	1475.48	28.93
COD (lb/T)	2.89	13.09
BOD** (lb/T)	1.71	12.29
Total Solids (lb/T)	5.99	2.09
Settleable Solids (ml/l)	0.2	---
Suspended Solids (lb/T)	0.58	11.35
Volatile Solids (%)	42.65	---
Total Nitrogen*** (lb/T)	0.26090	8.56
NO_3^- (lb-N/T)	0.0025	26.00
NO_2^- (lb-N/T)	0.0000	0.00
NH_3 (lb-N/T)	0.0000	0.00
Organic N (lb-N/T)	0.2584	8.95
Total Phosporus (lb/T)	0.0295	7.82
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0030	1.63
Inorganic P (lb/T)	0.0074	2.99
Total Soluble P (lb/T)	0.0209	7.09
pH	7.3	---
Dissolved Oxygen (mg/l)	11.73	---
Temperature (°C)	4.27	---

---

*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.59.

***Calculated by summing components.

Table 15. Section Cooker Overflow Characteristics Plant No. 2 (2 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	1.10	---	---	---
(gpT)	92.8	---	---	1.82
COD (lb/T)	7.28	6.38-8.19	1.29	32.97
BOD** (lb/T)	5.10	4.47-5.73	---	36.65
Total Solids (lb/T)	11.09	10.68-11.50	0.57	3.87
Settleable Solids (ml/l)	2.8	2.1-3.5	0.99	---
Suspended Solids (lb/T)	1.27	1.24-1.31	0.52	24.85
Volatile Solids (%)	59.13	---	1.24	---
Total Nitrogen*** (lb/T)	1.04912	1.01186-1.08628	---	34.44
NO_3^- (lb-N/T)	0.000076	0.000067-0.000085	0.000013	0.79
$NO_2^=$ (lb-N/T)	0.000052	---	---	67.53
NH_3 (lb-N/T)	0.0982	0.0921-0.1043	0.0086	65.16
Organic N (lb/T)	0.9508	0.9197-0.9819	0.0440	2.56
Total Phosphorus (lb/T)	0.0740	0.0604-0.0875	0.0192	19.61
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0233	0.0082-0.0384	0.0214	12.63
Inorganic P (lb/T)	0.0431	0.0335-0.0527	0.0136	17.42
Total Soluble P (lb/T)	0.0446	0.0369-0.0552	0.0110	15.13
pH	8.7	8.6-8.7	---	---
Dissolved Oxygen (mg/l)	---	---	---	---
Temperature (°C)	---	---	---	---

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*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.70.

***Calculated by summing components.

Table 16. Cooling Tank Overflow Characteristics Plant No. 2 (1 sample)

Parameter	Mean	% of Plant Total
Flow (gpm)*	18.5	---
(gpT)	1351.30	26.49
COD (lb/T)	1.06	4.8
BOD** (lb/T)	0.53	3.81
Total Solids (lb/T)	1.81	0.63
Settleable Solids (ml/l)	0.3	---
Suspended Solids (lb/T)	0.24	4.70
Volatile Solids (%)	69.55	---
Total Nitrogen*** (lb/T)	0.1164	3.82
NO_3^- (lb-N/T)	0.0028	29.11
NO_2^- (lb-N/T)	0.0000	0.00
NH_3 (lb-N/T)	0.0000	0.00
Organic N (lb/T)	0.1138	3.94
Total Phosphorus (lb/T)	0.0282	7.47
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0153	8.29
Inorganic P (lb/T)	0.0192	7.76
Total Soluble P (lb/T)	0.0192	6.51
pH	7.0	---
Dissolved Oxygen (mg/l)	---	---
Temperature (°C)	---	---

---

*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.50.

***Calculated by summing components.

Table 17. Picking Area Washwater Characteristics Plant No. 2 (4 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	30.34 (0.42 hr)	24.7-42.8	8.39	---
(gpT)	256.23	---	62.70	5.02
COD (lb/T)	1.19	0.97-1.57	0.28	5.39
BOD** (lb/T)	0.67	0.54-0.88	---	4.81
Total Solids (lb/T)	3.97	2.62-5.42	1.29	1.39
Settleable Solids (ml/l)	2.3	1.1-3.5	1.0	---
Suspended Solids (lb/T)	0.38	0.29-0.47	0.07	7.44
Volatile Solids (%)	31.74	18.65-37.15	8.76	---
Total Nitrogen*** (lb/T)	0.1571	0.1282-0.2248	---	5.16
NO_3^- (lb-N/T)	0.0005	0.0003-0.0007	0.0002	5.20
NO_2^- (lb-N/T)	0.000	---	---	0.00
NH_3 (lb-N/T)	0.0038	0.0026-0.0084	0.0035	2.52
Organic N (lb/T)	0.1528	0.1253-0.2157	0.0422	5.29
Total Phosphorus (lb/T)	0.0221	0.0193-0.0257	0.0033	5.86
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0149	0.0141-0.0154	0.0006	8.08
Inorganic P (lb/T)	0.0169	0.0154-0.0178	0.0013	6.83
Total Soluble P (lb/T)	0.0194	0.0184-0.0210	0.0014	6.58
pH	8.0	7.7-8.1	---	---
Dissolved Oxygen (mg/l)	12.37	12.1-12.5	0.23	---
Temperature (°C)	8.3	7.0-12.2	2.60	---

---

*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.56.

***Calculated by summing components.

Table 18. Crab Shell Flume Water Characteristics Plant No. 2 (4 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total ****
Flow (gpm)*	31.40	23.4-37.1	6.27	---
(gpT)	4025.95	---	1850.62	44.13
COD (lb/T)	5.08	3.57-6.37	1.15	18.70
BOD** (lb/T)	3.40	2.39-4.27	---	19.64
Total Solids (lb/T)	9.50	4.60-12.00	4.23	3.21
Settleable Solids (ml/l)	0.3	0.2-0.4	0.12	---
Suspended Solids (lb/T)	1.06	0.78-1.39	0.27	17.18
Volatile Solids (%)	56.82	53.8-61.85	4.39	---
Total Nitrogen*** (lb/T)	0.7052	0.31570-0.9936	---	19.65
NO_3^- (lb-N/T)	0.0084	0.0038-0.0131	0.0039	46.63
NO_2^- (lb-N/T)	0.0000	---	---	0.00
NH_3 (lb-N/T)	0.0291	0.0000-0.0415	0.0197	16.30
Organic N (lb/T)	0.6677	0.3119-0.9390	0.2607	18.79
Total Phosphorus (lb/T)	0.1222	0.0742-0.1595	0.0392	24.46
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0629	0.0418-0.0889	0.0233	25.42
Inorganic P (lb/T)	0.0763	0.0501-0.1111	0.0272	23.94
Total Soluble P (lb/T)	0.0955	0.0501-0.1185	0.0309	24.47
pH	7.3	7.2-7.9	---	---
Dissolved Oxygen (mg/l)	12.02	11.3-12.6	0.45	---
Temperature (°C)	6.86	4.9-9.5	1.93	---

---

*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.67.

***Calculated by summing components.

****These percentages include the shell flume with the other unit processes to comprise the total plant discharge.

Table 19. Brine Tank Discrete Discharge Characteristics Plant No. 2 (4 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	0.88	---	---	---
(gpT)	96.9	---	---	1.90
COD (lb/T)	5.0	4.22-5.69	0.69	22.64
BOD** (lb/T)	2.65	2.24-3.02	---	19.04
Total Solids (lb/T)	193.94	155.66-243.47	43.00	67.70
Settleable Solids (ml/l)	83.3	70-95	12.6	---
Suspended Solids (lb/T)	1.75	1.20-2.21	0.42	34.25
Volatile Solids (%)	18.7	4.84-33.6	16.0	---
Total Nitrogen*** (lb/T)	0.80916	0.63612-0.95662	---	26.56
NO_3^- (lb-N/T)	0.00004	0.00000-0.00009	0.00003	0.415
NO_2^- (lb-N/T)	0.000025	0.00002-0.00003	0.000007	32.47
NH_3 (lb-N/T)	0.0260	0.0185-0.0356	0.0083	17.25
Organic N (lb/T)	0.7831	0.6176-0.9209	0.1535	27.14
Total Phosphorus (lb/T)	0.1092	0.0818-0.1634	0.0372	28.93
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0456	0.0374-0.0567	0.0082	24.72
Inorganic P (lb/T)	0.0642	0.0504-0.1016	0.0250	25.95
Total Soluble P (lb/T)	0.0850	0.0818-0.0921	0.0048	28.83
pH	7.5	7.3-7.7	---	---
Dissolved Oxygen (mg/l)	11.32	---	0.28	---
Temperature (°C)	7.89	5.0-11.8	2.74	---

*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.53.

***Calculated by summing components.

Table 20. Primary Brine Rinsewater Characteristics Plant No. 2 (4 samples)

Parameter	Mean	Range	Standard Deviation	% of Total	% of Plant Total
Flow (gpm)*	6.48	5.1-9.1	1.76	50.63	---
(gpT)	806.26	---	297.98	50.31	15.81
COD (lb/T)	1.82	1.19-2.12	0.43	47.03	8.24
BOD** (lb/T)	1.31	0.86-1.53	---	46.95	9.41
Total Solids (lb/T)	49.38	30.93-77.30	19.98	72.05	17.24
Settleable Solids (ml/l)	0.37	0.3-0.5	0.12	---	---
Suspended Solids (lb/T)	0.38	0.30-0.52	0.10	65.52	7.44
Volatile Solids (%)	3.33	2.8-3.9	0.48	---	---
Total Nitrogen*** (lb/T)	0.23480	0.16410-0.26930	---	40.83	7.71
NO_3^- (lb-N/T)	0.0016	0.0008-0.0023	0.0006	50.00	16.63
NO_2^- (lb-N/T)	0.0000	---	---	0.00	0.00
NH_3 (lb-N/T)	0.0115	0.0029-0.0147	0.0075	50.66	7.63
Organic N (lb/T)	0.2217	0.1604-0.2523	0.0417	40.37	7.68
Total Phosphorus (lb/T)	0.0429	0.0339-0.0585	0.0135	42.77	11.37
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0343	0.0222-0.0472	0.0128	46.29	18.59
Inorganic P (lb/T)	0.0374	0.0247-0.0499	0.0132	45.50	15.12
Total Soluble P (lb/T)	0.0420	0.0333-0.0479	0.0077	45.49	14.25
pH	6.9	6.8-7.1	---	---	---
Dissolved Oxygen (mg/l)	12.03	---	0.29	---	---
Temperature (°C)	6.60	---	2.16	---	---

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*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.72.

***Calculated by summing components.

Table 21. Secondary Brine Rinsewater Characteristics Plant No. 2 (4 samples)

Parameter	Mean	Range	Standard Deviation	% of Total	% of Plant Total
Flow (gpm)*	6.32	5.33-7.53	0.90	49.37	---
(gpT)	796.33	---	348.11	49.69	15.63
COD (lb/T)	2.05	1.80-2.23	0.18	52.97	9.26
BOD** (lb/T)	1.48	1.30-1.61	---	53.05	10.64
Total Solids (lb/T)	19.16	15.28-25.76	4.74	27.95	6.69
Settleable Solids (ml/l)	0.3	0.1-0.4	0.153	---	---
Suspended Solids (lb/T)	0.20	0.17-0.21	0.02	34.48	2.14
Volatile Solids (%)	12.83	10.9-13.5	1.14	---	---
Total Nitrogen*** (lb/T)	0.3403	0.26910-0.40570	---	59.17	11.17
NO_3^- (lb-N/T)	0.0016	0.0007-0.0026	0.0008	50.00	16.63
$NO_2^=$ (lb-N/T)	0.0000	---	---	0.00	0.00
NH_3 (lb-N/T)	0.0112	0.0065-0.0153	0.0036	49.34	7.43
Organic N (lb/T)	0.3275	0.2619-0.3878	0.0516	59.63	11.35
Total Phosphorus (lb/T)	0.0574	0.0497-0.0757	0.0123	57.23	15.21
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0398	0.0335-0.0550	0.0103	53.71	21.57
Inorganic P (lb/T)	0.0448	0.0390-0.0616	0.0112	55.50	18.11
Total Soluble P (lb/T)	0.0524	0.0460-0.0678	0.0104	55.51	17.77
pH	7.1	7.1-7.2	---	---	---
Dissolved Oxygen (mg/l)	12.00	---	0.33	---	---
Temperature (°C)	6.69	5.0-10.0	2.02	---	---

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*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.72.

***Calculated by summing components.

Table 22. Combined Wastewater Characteristics Plant No. 3

Parameter	Without Butchering Flume		With Butchering Flume	
	Mean	Range	Mean	Range
Flow (gpm)*	---	---	---	---
(gpT)	5010.8	4216.9-5989.6	6244.3	5450.43-7223.13
COD (lb/T)	33.02	25.84-39.02	38.96	30.40-47.16
BOD** (lb/T)	21.3	17.0-20.06	25.32	25.00-30.45
Total Solids (lb/T)	132.60	89.49-181.26	140.76	95.84-190.02
Settleable Solids (ml/l)	703.6	609.6-841.7	711.7	609.8-842.0
Suspended Solids (lb/T)	5.76	3.94-8.18	6.23	4.24-8.88
Volatile Solids (%)	17.9	15.8-21.0	23.5	21.1-26.6
Total Nitrogen*** (lb/T)	4.2375	3.16752-5.11102	4.79140	3.50562-5.91162
NO_3^- (lb-N/T)	0.0076	0.00564-0.00939	0.0086	0.00614-0.01069
NO_2^- (lb-N/T)	0.00062	0.00038-0.00664	0.00072	0.00038-0.00684
NH_3 (lb-N/T)	0.2437	0.1573-0.3146	0.2638	0.1650-0.3506
Organic N (lb/T)	3.9856	3.0004-4.7808	4.5132	3.3303-5.5437
Total Phosphorus (lb/T)	0.4285	0.3222-0.5746	0.4625	0.3462-0.6273
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.1758	0.1204-0.2545	0.1876	0.1236-0.2719
Inorganic P (lb/T)	0.2781	0.2134-0.3426	0.3007	0.2334-0.3678
Total Soluble P (lb/T)	0.3600	0.2586-0.4876	0.3874	0.2758-0.5280
pH	7.7	7.2-8.3	7.6	---
Dissolved Oxygen (mg/l)	---	---	---	---
Temperature (°C)	---	---	---	---

*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.69.

***Calculated by summing components.

Table 23. Cooling and Preliminary Rinsewater Characteristics Plant No. 3 (3 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	58.0	50.3-71.0	---	---
(gpT)	3163.0	2659.9-3811.0	589.1	63.12
COD (lb/T)	10.99	10.40-11.65	0.63	33.28
BOD** (lb/T)	8.13	7.70-8.62	---	38.10
Total Solids (lb/T)	24.51	14.80-43.70	16.62	18.48
Settleable Solids (ml/l)	0.3	0.1-0.5	0.2	---
Suspended Solids (lb/T)	1.04	0.68-1.55	0.46	18.06
Volatile Solids (%)	---	---	---	---
Total Nitrogen*** (lb/T)	1.1570	1.1079-1.1986	---	27.30
NO_3^- (lb-N/T)	0.0051	0.0038-0.0063	0.0018	67.11
NO_2^- (lb-N/T)	0.0004	0.0003-0.0005	0.0001	64.52
NH_3 (lb-N/T)	0.0519	0.0356-0.0705	0.0176	21.30
Organic N (lb/T)	1.0996	1.0682-1.1213	0.0278	27.59
Total Phosphorus (lb/T)	0.0775	0.0755-0.0795	0.0020	18.09
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0245	0.0171-0.0305	0.0068	13.94
Inorganic P (lb/T)	0.0457	0.0404-0.0540	0.0073	16.43
Total Soluble P (lb/T)	0.0643	0.0516-0.0776	0.0130	17.86
pH	7.6	7.5-7.9	---	---
Dissolved Oxygen (mg/l)	11.80	11.33-12.10	0.41	---
Temperature (°C)	8.02	5.43-10.00	2.35	---

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*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.74.

***Calculated by summing components.

Table 24. Butchering Flume Wastewater Characteristics Plant No. 3 (3 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	21.65	---	3.19	---
(gpT)	1233.53	---	491.84	19.75
COD (lb/T)	5.94	4.56-8.14	1.93	15.25
BOD**(lb/T)	3.98	3.06-5.45	---	15.72
Total Solids (lb/T)	8.16	6.35-10.76	2.31	5.80
Settleable Solids (ml/l)	0.2	0.2-0.3	0.05	---
Suspended Solids (lb/T)	0.47	0.30-0.70	0.23	7.54
Volatile Solids (%)	55.6	52.5-55.9	2.96	---
Total Nitrogen*** (lb/T)	0.5488	0.33810-0.8006	---	11.45
NO_3^- (lb-N/T)	0.0010	0.0005-0.0015	0.0007	11.63
NO_2^- (lb-N/T)	0.0001	0.0000-0.0002	0.0001	13.89
NH_3 (lb-N/T)	0.0201	0.0077-0.0360	0.0145	7.62
Organic N (lb/T)	0.5276	0.3299-0.7629	0.2189	11.69
Total Phosphorus (lb/T)	0.0340	0.0240-0.0527	0.0162	7.35
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0118	0.0032-0.0174	0.0072	6.29
Inorganic P (lb/T)	0.0226	0.0200-0.0252	0.0037	7.52
Total Soluble P (lb/T)	0.0274	0.0172-0.0404	0.0119	7.07
pH	7.3	7.3-7.4	---	---
Dissolved Oxygen (mg/l)	12.30	12.03-12.43	0.23	---
Temperature (°C)	6.01	3.97-7.90	1.97	---

*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.67.

***Calculated by summing components.

Table 25. Cooking Water Characteristics Plant No. 3 (3 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	---	---	---	---
(gpT)	118.7	---	---	2.37
COD (lb/T)	6.75	4.24-9.15	2.46	20.44
BOD** (lb/T)	4.52	2.84-6.13	---	21.18
Total Solids (lb/T)	12.45	7.39-15.49	4.41	9.39
Settleable Solids (ml/1)	12.5	4.5-24.0	10.2	---
Suspended Solids (lb/T)	0.85	0.43-1.07	0.36	14.76
Volatile Solids (%)	58.6	56.5-61.1	2.32	---
Total Nitrogen*** (lb/T)	1.0817	0.56672-1.4548	---	25.53
NO_3^- (lb-N/T)	0.00012	0.00004-0.00019	0.00011	1.58
NO_2^- (lb-N/T)	0.0001	0.00008-0.00012	0.00003	16.13
NH_3 (lb-N/T)	0.1064	0.0541-0.1362	0.0455	43.66
Organic N (lb/T)	0.9751	0.5125-1.3183	0.4159	24.47
Total Phosphorus (lb/T)	0.0762	0.0385-0.1107	0.0362	17.78
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0172	0.0018-0.0438	0.0231	9.78
Inorganic P (lb/T)	0.0435	0.0237-0.0572	0.0176	15.64
Total Soluble P (lb/T)	0.0598	0.0218-0.1107	0.0458	16.61
pH	8.5	8.2-8.8	---	---
Dissolved Oxygen (mg/1)	---	---	---	---
Temperature (°C)	---	---	---	---

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*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.67.

***Calculated by summing components.

Table 26. Rinse Tank Overflow Characteristics Plant No. 3 (3 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	15.2	14.5-15.7	---	---
(gpT)	867.3	809.0-922.9	57.0	17.31
COD (lb/T)	4.50	3.76-4.96	0.65	13.63
BOD** (lb/T)	2.93	2.44-3.22	---	13.73
Total Solids (lb/T)	29.87	24.15-35.89	5.87	22.53
Settleable Solids (ml/l)	0.9	0.5-1.2	0.4	---
Suspended Solids (lb/T)	0.56	0.32-0.79	0.24	9.72
Volatile Solids (%)	20.4	19.0-21.3	1.17	---
Total Nitrogen*** (lb/T)	0.78045	0.72440-0.87428	---	18.42
NO_3^- (lb-N/T)	0.0011	0.0008-0.0013	0.0003	14.47
NO_2^- (lb-N/T)	0.00005	0.00000-0.00008	0.00004	8.06
NH_3 (lb-N/T)	0.0305	0.0287-0.0325	0.0019	12.51
Organic N (lb/T)	0.7488	0.6949-0.8404	0.0797	18.79
Total Phosphorus (lb/T)	0.1141	0.1116-0.1181	0.0035	26.63
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0790	0.0646-0.0881	0.0126	44.94
Inorganic P (lb/T)	0.0872	0.0731-0.0978	0.0127	31.36
Total Soluble P (lb/T)	0.1082	0.1001-0.1157	0.0078	30.05
pH	7.8	7.5-8.1	---	---
Dissolved Oxygen (mg/l)	12.27	11.93-12.68	0.38	---
Temperature (^oC)	6.9	4.95-8.7	1.9	---

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*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.65.

***Calculated by summing components.

Table 27. Brine Tank Discrete Discharge Characteristics Plant No. 3 (5 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	0.53	---	---	---
(gpT)	33.3	---	---	0.66
COD (lb/T)	5.40	3.10-6.29	1.31	16.35
BOD** (lb/T)	2.86	1.64-3.33	---	13.40
Total Solids (lb/T)	54.63	35.64-67.48	13.02	41.20
Settleable Solids (ml/l)	680.0	600.0-800.0	90.8	---
Suspended Solids (lb/T)	1.86	1.28-2.76	0.58	32.29
Volatile Solids (%)	13.98	8.7-28.0	8.02	---
Total Nitrogen*** (lb/T)	0.75061	0.45730-0.95142	---	17.71
NO_3^- (lb-N/T)	0.0000	0.0000-0.0000	---	0.00
NO_2^- (lb-N/T)	0.00001	0.00000-0.00002	0.00001	1.61
NH_3 (lb-N/T)	0.0244	0.0143-0.0324	0.0067	10.01
Organic N (lb/T)	0.7262	0.4430-0.9190	0.1807	18.22
Total Phosphorus (lb/T)	0.0849	0.0403-0.1759	0.0555	19.81
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0179	0.0068-0.0435	0.0151	10.18
Inorganic P (lb/T)	0.0503	0.0369-0.0685	0.0137	18.09
Total Soluble P (lb/T)	0.0625	0.0322-0.1067	0.0344	17.36
pH	7.4	7.1-7.8	---	---
Dissolved Oxygen (mg/l)	9.4	9.0-10.1	0.42	---
Temperature (°C)	13.2	11.0-15.7	1.71	---

*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.53.

***Calculated by summing components.

Table 28. Butchering Area Washwater Characteristics Plant No. 3 (2 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	73.7	59.4-88.0	20.2	---
(gpT)	530.6	475.2-586.1	78.4	10.59
COD (lb/T)	2.94	---	---	8.90
BOD** (lb/T)	1.68	---	---	7.87
Total Solids (lb/T)	2.88	1.92-3.85	1.36	2.17
Settleable Solids (ml/l)	2.0	1.0-3.0	1.4	---
Suspended Solids (lb/T)	0.60	0.57-0.62	0.04	10.42
Volatile Solids (%)	58.7	58.6-58.9	0.21	---
Total Nitrogen*** (lb/T)	0.19093	0.11660-0.26425	---	4.51
NO_3^- (lb-N/T)	0.0009	0.0008-0.0010	0.00014	11.84
$NO_2^=$ (lb-N/T)	0.00003	0.00000-0.00005	0.000035	4.84
NH_3 (lb-N/T)	0.0158	0.0137-0.0178	0.0029	6.48
Organic N (lb/T)	0.1742	0.1021-0.2463	0.1020	4.37
Total Phosphorus (lb/T)	0.0298	---	---	6.95
Ortho-$PO_4^{\equiv}$ (lb-P/T)	0.0133	---	---	7.57
Inorganic P (lb/T)	0.0208	---	---	7.48
Total Soluble P (lb/T)	0.0298	---	---	8.28
pH	7.6	7.6-7.7	---	---
Dissolved Oxygen (mg/l)	11.9	11.7-12.2	0.35	---
Temperature (°C)	7.0	5.0-9.0	2.83	---

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*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.57.

***Calculated by summing components.

Table 29. Picking Area Washwater Characteristics Plant No. 3 (4 samples)

Parameter	Mean	Range	Standard Deviation	% of Plant Total
Flow (gpm)*	48.6	26.2-86.5	---	---
(gpT)	298.0	120.8-517.6	199.1	5.95
COD (lb/T)	2.44	1.40-4.03	1.13	7.39
BOD** (lb/T)	1.22	0.70-2.02	---	5.72
Total Solids (lb/T)	8.26	5.59-14.85	4.42	6.23
Settleable Solids (ml/l)	7.9	3.5-13.0	4.2	---
Suspended Solids (lb/T)	0.85	0.41-1.39	0.43	14.76
Volatile Solids (%)	27.16	15.0-41.0	13.04	---
Total Nitrogen*** (lb/T)	0.27683	0.19080-0.36137	---	6.53
NO_3^- (lb-N/T)	0.0004	0.0002-0.0006	0.0002	5.26
NO_2^- (lb-N/T)	0.00003	0.00000-0.00007	0.00004	4.84
NH_3 (lb-N/T)	0.0147	0.0109-0.0252	0.0070	6.03
Organic N (lb/T)	0.2617	0.1797-0.3355	0.0648	6.57
Total Phosphorus (lb/T)	0.0460	0.0265-0.0606	0.0142	10.74
Ortho-$PO_4^=$ (lb-P/T)	0.0239	0.0168-0.0353	0.0801	13.59
Inorganic P (lb/T)	0.0306	0.0185-0.0443	0.0108	11.00
Total Soluble P (lb/T)	0.0354	0.0231-0.0471	0.0105	9.83
pH	8.4	8.1-8.6	---	---
Dissolved Oxygen (mg/l)	12.1	11.8-12.4	0.29	---
Temperature (°C)	6.8	6.0-7.5	0.75	---

*Total volume/total time during periods when operation was sampled.

**Calculated from COD using BOD/COD = 0.50

***Calculated by summing components.

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SUMMARY: FOOD WASTE RESEARCH--WHERE DO WE GO FROM HERE?

by

Dale A. Carlson*

During the past three days of a very fine conference, we have listened to reviews of nearly twenty types of food processing waste characteristics, looked at a number of process modifications, and heard of a dozen treatment methods applied to the food processing industry. At this point, the question becomes one of relating all the information obtained to some integrated body of knowledge that can be applied to our daily waste treatment problems in the year ahead. As well, the information needs to be used to provide for our national needs, to enhance industrial productivity, and, at the same time, preserve our natural life systems as we know them. And, finally, in assessment, we need to establish the goals for the 1973 Symposium.

Some of the papers presented were critical of present processing and treatment methods, some reviewed stream qualities and handling methods for wastes, some noted that earlier processing methods, with modification, could be more efficient than those in use today. Other speakers discussed various process changes and covered possible future regulations at the Federal level.

Typical examples of the papers include Stone's discussion of a process change to provide dry caustic peeling for peaches which reduced the pounds per day of organic matter discharged from the process and thereby reduced the pollution load. But also, the process was less abusive to the fruit, lowered operating costs, and reduced fresh water requirements by 90 percent.

Lund noted that the individual quick blanch reduced effluents from 68 to 99 percent depending on the crop processed. Several authors looked at treatment processes such as membrane filtration for soy whey treatment. Boyle and Polkowski evaluated the effectiveness of aerated lagoons for cheese whey wastes. They found adequate treatment but noted that the waste stream was nitrogen deficient.

Soderquist, in reporting on an ongoing study, noted that in recent years the handling of wastes in the West Coast seafood industry has been upgraded while Claggett reported on the improvement in fish wastes solids removal with caustic-alum treatment combined with air flotation. He noted that the demonstration unit operated better than the pilot unit and that the value of recovered solids should offset the sum of unit operation and sludge recovery costs.

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*Professor and Chairman, Department of Civil Engineering, University of Washington, Seattle, Washington 98105.

Taylor and Dostal examined the treatability of wheat starch processing wastes using the anaerobic trickling filter and encouraged further studies to develop the characteristics of the anaerobic filter as a rugged resilient treatment unit with removal efficiencies not affected by down times of as long as 30 days.

Cywin and LaGraff presented previews of HR 11896 mentioning possible levels for treatment and collection. Also discussed were enforcement activities including citizen participation and user charges. Continued Federal-State cooperation was encouraged.

And finally, papers on Friday included discussions of dried cattle rumen as a useful channel catfish feed and the use of the biodisc in initial controlled studies on the treatability of potato wastes. With nutrient addition, Cochrane and Dostal obtained COD removals of 91-95 percent for potato granules.

Russell discussed secondary treatment and polishing of winery wastes including the icing problems of aerated lagoons in cold climates while Schwartz presented a review of biological treatment of brewery wastes and commented on the treatability problems associated with high BOD loads that are readily degradable.

The gist of the papers was that the total overall mass balance is being accepted as a realistic approach to industrial process evaluation. The diagram shown in Figure 1 notes that for every industrial process the total of the pounds of raw material (a) plus water (b) plus air (c) entering the process must equal the total of pounds of product (x), plus by-products (y) and waste products (z) leaving the system. This simple mass balance says then that

lb of "a" + lb of "b" + lb of "c" = lb of "x" + lb of "y" + lb of "z"

Of course, the energy balance can likewise be drawn for the process so that in Figure 2 the industrial process raw materials, products, waste products, and energy steps must necessarily develop for all the operations incorporated in actually providing the product. The center column of Figure 2 lists some of the aspects of processing that must be considered.

The Figures 1 and 2 apply as well to all of man's construction activities, and are involved with national economics as well as the entire world system of commerce and interacting living communities. The intricacies and complexities involved with evaluating the totality of these balances necessitate not only cooperation and good will between industry, government, and universities but also world-wide cooperation in environmental quality control, process innovation, and market development. Perhaps only when proper evaluation of the balances is achieved and the total implications of change in the processes are understood, can we properly make the proper selection of alternatives for use of our natural resources.

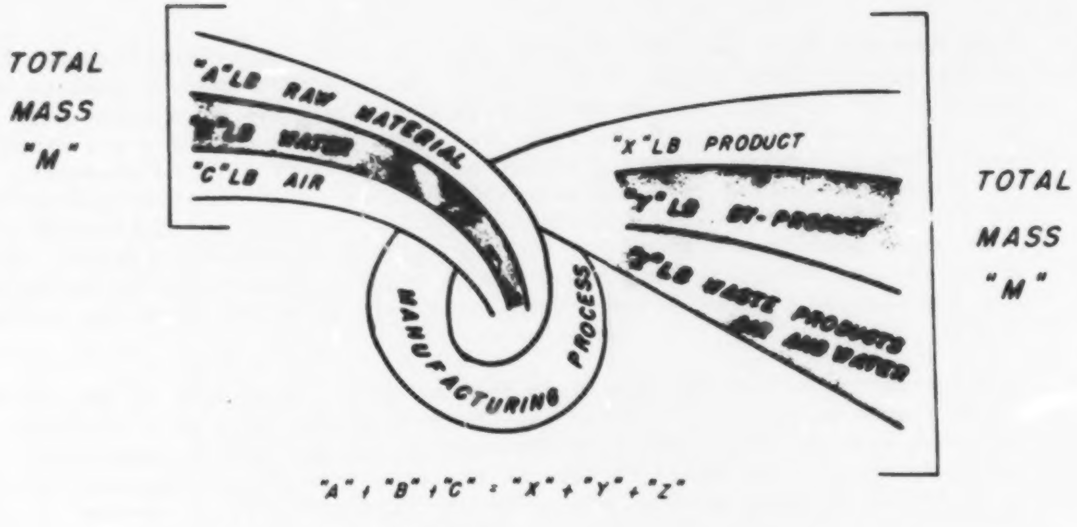
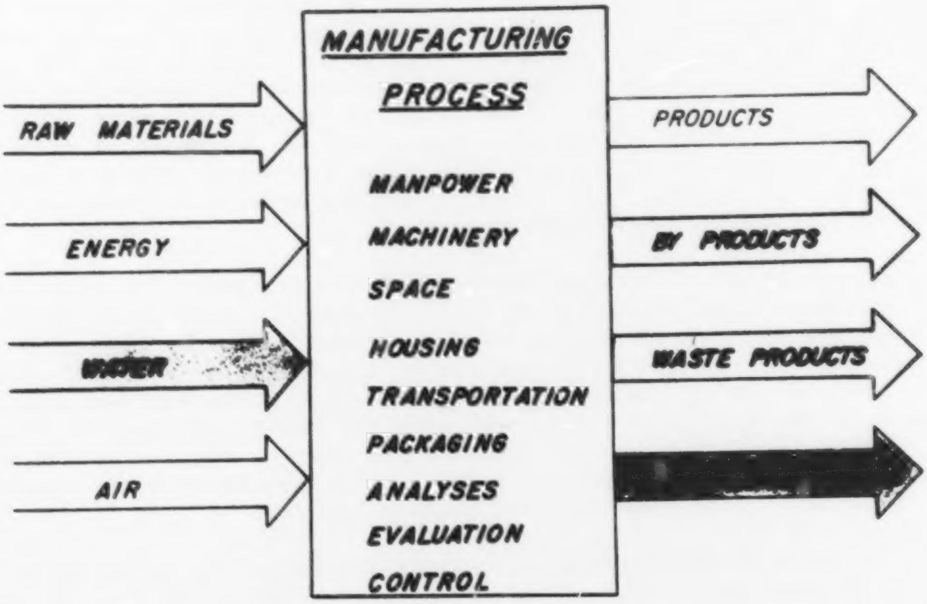

TOTAL MASS "M"
"A" LB RAW MATERIAL
"B" LB WATER
"C" LB AIR
MANUFACTURING PROCESS
"X" LB PRODUCT
"Y" LB BY-PRODUCT
"Z" LB WASTE PRODUCTS AIR AND WATER
TOTAL MASS "M"
"A" + "B" + "C" = "X" + "Y" + "Z"

Figure 1


MANUFACTURING PROCESS
RAW MATERIALS
ENERGY
WATER
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MANPOWER
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PACKAGING
ANALYSES
EVALUATION
CONTROL
PRODUCTS
BY PRODUCTS
WASTE PRODUCTS

FIGURE 2 A TYPICAL MANUFACTURING PROCESS

This does not mean, however, that we can wait with improvements until the entire interlocking system is evaluated. It does mean that we need to be aware of the enormity of and the perturbation qualities of the balances and seek to logically evaluate the systems. What will be required are innovative approaches to remove current roadblocks to further process enhancement. In environmental control, studies must be continued on alternative approaches to alleviate environmental degradation. While tertiary and quaternary treatment steps must be a part of the tools available for quality control, process modification, recycling, and reuse should be considered as prime mechanisms for diminishing product losses, conserving materials, and reducing production costs.

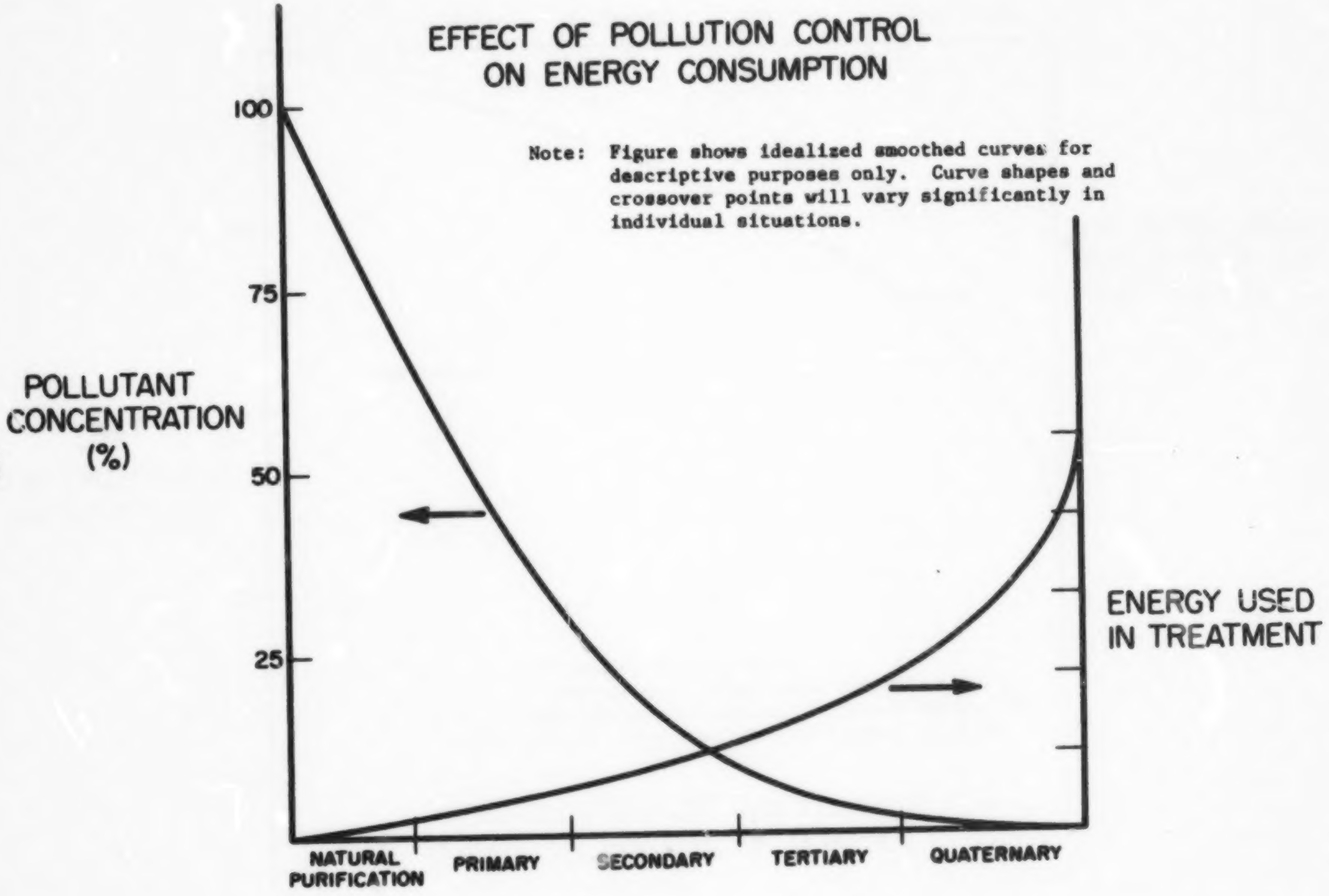
Nevertheless, it must be recognized that no single mechanism is apt often to be the total panacea, and secondly it is obvious that, as a corollary to the mass balance, it is not possible to use raw materials to construct anything new in this world without at the same time destroying some other part of the existing environment. Thirdly, the treatment processes added to a system to reduce environmental pollution are in themselves processes which require energy, money, and materials and thereby in their own right can create environmental pollution problems. Finally, it is quite often possible that the alleviation of a solid wastes problem will be detrimental to the water or air environment and vice versa.

Thus, in Figure 3, an idealized theoretical diagram indicates that the energy and cost requirements can go up as greater and greater removal of a pollutant is required. In Figure 4, the concomitant pollutions added to the environment in, say, obtaining manufacturing, processing and transporting chemicals, in providing the energy for chemical addition and then removing and disposing of the sludge produced may at some point exceed the amount removed. Other mechanisms could be brought into play for reducing the waste load which do not have this great an environmental effect. A number of alternatives exist at this point including combining waste streams for symbiotic removal opportunities, process modification and renovation, recycling, and increased quality control.

Beyond the material systems listed above are the needs for industries to encompass human relations in their attempts to make their processes compatible with the environment and with man's desires. Not only is it necessary that the public become aware of industry's efforts to provide desirable products without undue environmental diruption, but also industry must provide information and incentives for public endorsement of alternatives providing feasible solutions to pollution control and public endorsement, as well, of the additional costs involved in providing those quality products with corresponding environmental quality control.

The future will require that innovation and incentive are integral mechanisms in maintaining national and industrial well being in the face of world economic and marketing difficulties. As unacceptable employment levels, inflationary spirals with concomitant lack of adequate increases in productivity, deteriorating trade balances, and gradual erosion of the position of the United States in international technological competition combine with

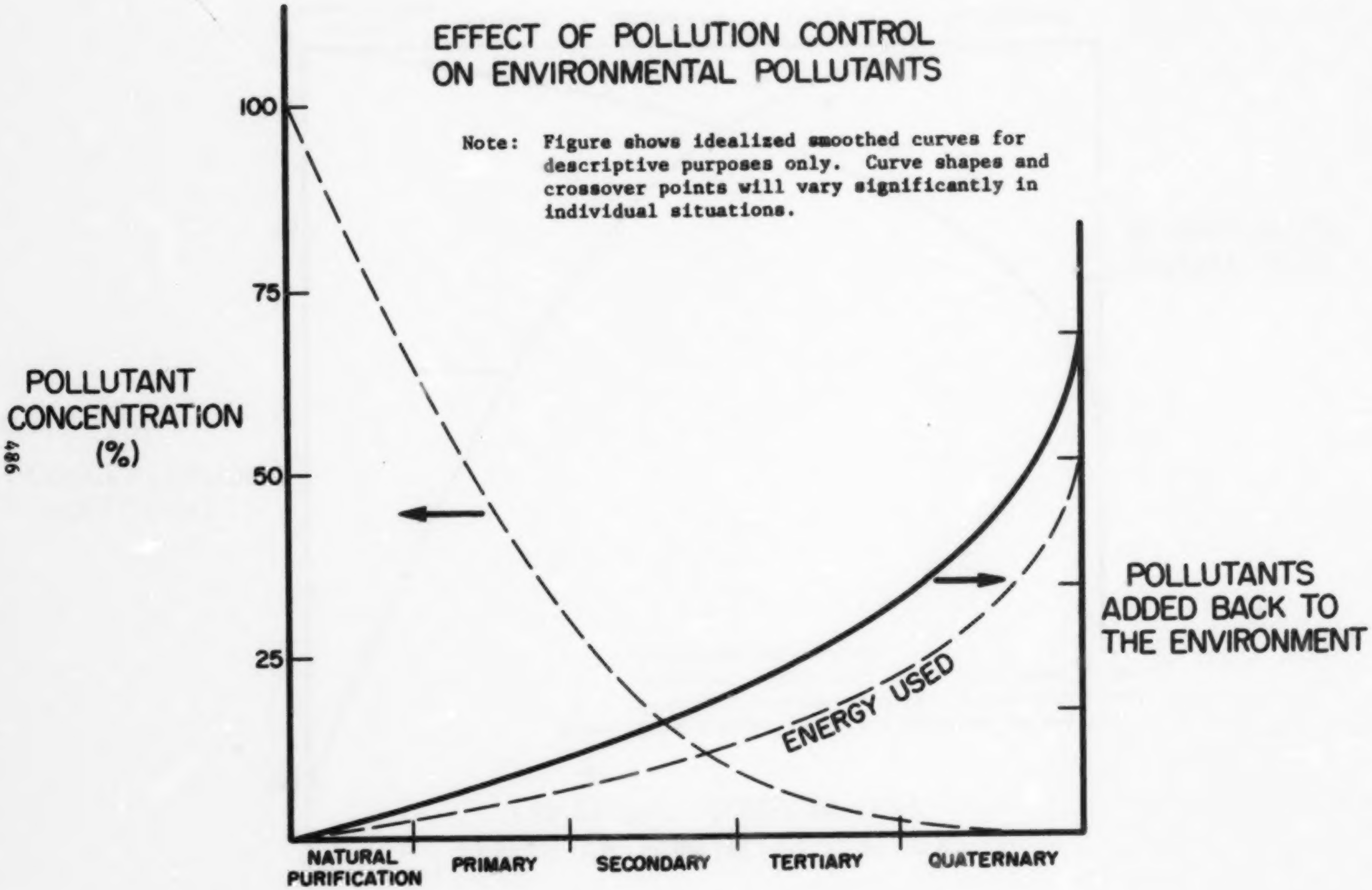
Figure 3



EFFECT OF POLLUTION CONTROL ON ENERGY CONSUMPTION

Note: Figure shows idealized smoothed curves for descriptive purposes only. Curve shapes and crossover points will vary significantly in individual situations.

Figure 4



EFFECT OF POLLUTION CONTROL ON ENVIRONMENTAL POLLUTANTS

Note: Figure shows idealized smoothed curves for descriptive purposes only. Curve shapes and crossover points will vary significantly in individual situations.

the unresolved problems of our society and the resolution of authority to force ever greater stresses on American leadership, it becomes daily more necessary for all of us, regardless of American heterogeneity problems, to strive toward solving our environmental quandaries as a team.

When economic progress is measured by ever expanding gross national product, there is a necessity for a continuous search for raw materials, empirical development of new materials and devices, maximizing of available labor and the availability of investment capital. To these activities must now be added: (1) the recognition of the limits to our natural resources and the limits to receptor capacities for wastes; (2) the need for disciplined use of our intellectual powers in understanding nature both for using its benefits and preserving its integrity; (3) recognition of the abilities of other nations to produce as well as or better than the United States, and thereby recognition of the need to learn from others, to observe and appreciate their culture as well as their techniques and thereby develop products to fit their culture, i.e. there is a developing need to amalgamate to a greater extent with world wants.

In order that we maintain both cultural and industrial viability in the future, it must now be evident that increasing GNP is not a sufficient goal in itself, but rather that industry, government, lay population, and universities coordinate their efforts to innovate, invent, and employ technology and philosophies which can provide the goals for men to strive for as responsible citizens of the country and the earth. This means that significant income fractions need to be relegated to both technological and sociological research to provide incentives for mankind, to identify blockages in our present system, and to enhance our current sociological and industrial systems. Finally, the need to accept philosophies that recognize quality in both product and work habits are of prime importance in maintaining a quality environment together with industrial and community well being.

As stated by Boydston, the Symposium goals are to provide an early forum for presenting the latest research in the food processing industry. In seeking greater international coverage of work on recycle, reuse, higher forms of treatment, and process improvement, the Symposium will be even more valuable in the years to come, and we look forward with interest to next year's papers. We trust that all of you will be promoting the development of another excellent set of presentations.

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REGISTRATION LIST

DONALD A. ADAMS
McFarland-Johnson-Gibbons
333 Front Street
Binghamton, NY 13905

ROGER L. ADAMS
Northwest Paper Company
Cioquet, MN 55720

WILLIAM H. ADLER
States Illam
New Orleans, LA 70116

O. E. ALBERTSON
Envirotech Systems, Inc.
P. O. Box 8158
San Francisco, CA 94128

C. HENRY ALLEN
Gerber Products Co.
460 Buffalo Road
Rochester, NY 14602

THOMAS S. ALLEN
Ethyl Corporation
2296 Hollydale Avenue
Baton Rouge, LA 70808

WILLIAM L. AMT
The Carborundum Company
P. O. Box 1269
Knoxville, TN 37720

GERRY B. ANDEEN
Michigan Technical University
Houghton, MI 49931

TED. R. ARNOLD
Westinghouse Electric Corp.
P. O. Box 9175
Philadelphia, PA 19113

THEODORE AUCOIN, JR.
Kaiser Aluminum & Chem. Corp.
P. O. Box 1600
Chalmette, LA 70043

DANIEL W. BAKER
National Marine Fisheries Service
Emerson Avenue
Gloucester, MA 01930

GREGORY J. BARBIER
L. S. U. N. O.
4622 Orleans
New Orleans, LA 70119

ROY W. BARNS
Triangle E By Products Co.
Harrisonburg, VA 22801

RONALD L. BARROW
E.P.A. - Southeast Water Laboratory
College Station Road
Athens, GA 30601

MARTHA I. BEACH
N.-Con Systems Co., Inc.
410 Boston Post Road
Larchmont, NY 10538

C. W. BEATTY
Stone & Webster Canada Limited
60 Adelaide Street
Toronto, Ontario, Canada

MALCOLM C. BEAVERSTOCK
UNIROYAL
Geismar, LA 70734

EDWARD R. BECK
General Mills, Inc.
9000 Plymouth Avenue, North
Minneapolis, MN 55427

ERNEST W. BECK, JR.
Spreckels Sugar Company
338 Green Oaks Drive
Atherton, CA 94025

H. O. BENSING
CPC International
4240 N. Northbrook
Peoria, IL 61614

J. H. BENTON
Ethyl Corporation
451 Florida
Baton Rouge, LA 70801

FERDINAND BESIK
Ontario Research Foundation
Sheridan Park
Mississauga, Ontario, Canada

ALLEN W. BETZ
Betz Engineering Sales Co.
7979 Earhart Boulevard
New Orleans, LA 70125

EDWARD T. L. BORIE
Walk, Haydel & Associates, Inc.
762 Baronne Street
New Orleans, LA 70113

CRAIG A. BRANDON
Clemson University
Clemson, SC 29631

DAN E. BROOKS
National Canners Association
1600 So. Jackson Street
Seattle, WA 98144

WILLARD R. BROSZ
Green Giant
LeSueur, MN 56058

DONALD R. BROWN
CPC International, Inc.
P. O. Box 345
Argo, IL 60501

WILLIAM F. BUCHOLZ
PCE, Inc.
3525 No. Causeway Blvd.
Suite 633
Metairie, LA 70002

CLAYTON D. CALLIHAN
Louisiana State University
Chemical Engineering Dept.
Baton Rouge, LA 70803

ROY E. CARAWAN
129 Schaub Hall
North Carolina State Univ.
Raleigh, NC 27607

CLARENCE J. CARLSON
U. S. National Marine Fisheries Serv.
Emerson Avenue
Gloucester, MA 01930

DALE A. CARLSON
201 More Hall
University of Washington
Seattle, WA 98195

DAVID J. CARVILLE
Barnard & Burk, Inc.
P. O. Box 15648
Baton Rouge, LA 70815

EDWIN A. CATALANO
USDA-ARS
1100 Robert E. Lee Blvd.
New Orleans, LA 70119

ROBERT E. CEROSKY
General Foods Corporation
250 North Street
White Plains, NY 10625

BROOKS D. CHURCH
North Star Research
3100 - 38th Avenue South
Minneapolis, MN 55406

FRED G. CLAGGETT
Fisheries Research Board
6640 N.W. Marine Drive
Vancouver, 8, B.C. Canada

CLIFF H. COLE
Universal Foods Corp.
325 North 27th Street
Milwaukee, WI 53208

JEFF COLLINS
National Marine Fisheries Service
P. O. Box 1064
Kodiak, AK 99615

NEWTON V. COLSTON
North Carolina State University
Box 5993
Raleigh, NC 27607

RAY S. CORKERN
1900 Robert E. Lee Boulevard
New Orleans, LA 70119

EDWIN COX, III
Edwin Cox Associates
P. O. Box 8025
Richmond, VA 23223

HOMER E. CROTTY
DuBois Chemical Research
3630 E. Kemper Road
Sharonville, OH 45240

R. E. DAUPHINEE
Crane-Env. Systems Division
6300 West Park - Suite 315
Houston, TX 77027

JAMES J. DAVIES
Roy F. Weston, Inc.
7380 Exchange Place
Baton Rouge, LA 70806

CHARLES H. DAVIS
Chas. T. Main, Inc.
1301 E. Morehead
Charlotte, NC 28212

ROGER A. DECAMP
National Canners Association
1600 S. Jackson Street
Seattle, WA 98144

DOMENIC DEFELICE
Beech-Nut, Inc., R&D Div.
460 Park Avenue
New York, NY 10022

JOHN S. DEMURLEY
Envirotech, Inc.
1620 U. S. Route 22
Union, NJ 07083

HARRY E. DERTON
Centrifugal & Mech. Ind.
146 President Street
St. Louis, MO 63118

B. E. DIETZ
1302 South Elm
Champaign, IL 61820

JESS C. DIETZ
Clark, Dietz & Associates
211 North Race Street
Urbana, IL 61801

EARL S. DOBBS
W. S. Nelson & Co., Inc.
1200 St. Charles Avenue
New Orleans, LA 70130

DONALD L. DOWNING
N.Y. State Agriculture Exp. Sta.
Cornell University
Geneva, NY 14456

EMIL F. DUL
Engineering Science, Inc.
185 Great Neck Road
Great Neck, NY 11021

ROBERT H. EINARSEN
Triangle E By Products Co.
P. O. Box 471
Harrisonburg, VA 22801

CRAIG S. EKERMEYER
Brown-Miller Company
P. O. Box 158
Wiggins, MS 39577

R. D. ELLENDER
Gulf South Research Inst.
P. O. Box 26500
New Orleans, LA 70126

WILLIAM ELLERS
Dorr Oliver
100 South York
Elmhurst, IL 60126

JIM ELSKEN
Dorr Oliver
Havemeyer Lane
Stamford, CT 06900

PETER M. EMERSON
Economic Research Service
500 - 12th Street, SW
Washington, DC 22150

WILLIAM F. ESCUDERO
Contadina Foods, Inc.
2906 Santa Fe Street
Riverbank, CA 95367

PAUL T. EUBANKS
Arthur G. McKee & Co.
10 So. Riverside Place
Chicago, IL 60606

PATRICK FALLON
British Embassy
3100 Massachusetts Dr.
Washington, DC 20008

LINWOOD E. FARMER
Tulane University
5220 Camp Street
New Orleans, LA 70115

JOHN W. FARQUHAR
American Frozen Food Institute
919 - 18th Street, N.W.
Washington, DC 20006

W. FLUEHRS
General Foods Corporation
1551 East Willow Street
Kankakee, IL 60901

IRA V. FORDYCE
American Crystal Sugar Co.
Box 357
E. Grand Forks, MN 56721

ROBERT W. FOSTER
E. I. duPont deNemours Co.
Box 1378
Louisville, KY 40201

REGINALD A. GALLOP
Head, Food Science Dept.
University of Manitoba
Winnipeg, Manitoba, Canada R3M 0H9

JEAN R. GEISMAN
Ohio State University
2001 Fyffe Ct.
Columbus, OH 43210

LOU C. GILDE
Campbell Soup Company
4119 King Avenue
Pennsauken, NJ 08109

DAVID R. V. GOLDING
Dole Company
Box 3380
Honolulu, HI 96801

JOHN H. GREEN
WSDC, NOAA, NMFS, FTP LAB
Regents Drive,
College Park, MD 20740

FRANCIS A. GRILLOT
F. C. Schaffer & Associates
185 Bellewood Drive
Baton Rouge, LA 70815

FRANK R. GROVES, JR.
Louisiana State University
1055 West Lakeview Drive
Baton Rouge, LA 70810

R. JAMES GUILBEAUX
Bruce Foods, Inc.
P. O. Box 1030
New Iberia, LA 70560

C. FRED GURNHAM
Gurnham & Associates, Inc.
223 West Jackson
Chicago, IL 60606

LEO F. HANEY
Calgon Corporation
P. O. Box 1346
Pittsburgh, PA 15230

DOUGLAS P. HARRISON
Louisiana State University
Department of Chemical Eng.
Baton Rouge, LA 70803

VERA C. HASLING
USDA - ARS - SMN
1100 Robert E. Lee Boulevard
New Orleans, LA 70119

HARRISON L. HATCH
Carnation Company
5045 Wilshire Boulevard
Los Angeles, CA 90036

RALPH C. HAUZEE
ICI - America
Vol. Army Ammunition Plant
Chattanooga, TN 37401

LEIGH C. HAYES
Amstar Corporation
7417 No. Peters Street
Arabi, LA 70032

ROBERT L. HILLER
Env. Protection Agency
1600 Patterson
Dallas, TX 75201

H. H. HINDS
Champlin Petroleum Co.
Fort Worth, TX 76107

FRED C. HOBSON
J. N. Pease Associates
P. O. Box 12725
Charlotte, NC 28205

JAMES C. IELASE
Archer Daniels Midland
P. O. Box 1470
Decatur, IL 62525

GILBERT S. JACKSON
Env. Protection Agency
Washington, DC 20460

KARL T. JOHNSON
Env. Protection Agency
Office of Refuse Act Programs
Washington, DC 20460

RICHARD H. JONES
Env. Engineering, Inc.
2324 S.W. 34th Street
Gainesville, FL 32601

ROBERT H. JOOST
Env. Pollution Control
Box 11
Oconomowoc, WI 53066

ALLEN M. KATSUYAMA
National Canners Association
1950 Sixth Street
Berkeley, CA 94710

HAROLD G. KEELER
Env. Protection Agency
Office of Research and Monitoring
Washington, DC 20460

PHILIP J. KELLER
DuPont - Experimental Station
Wilmington, DE 19898

GARY W. KEMPF
Ayres, Lewis, Norris, & May, Inc.
3983 Research Park Drive
Ann Arbor, MI 48104

ROBERT P. KINGSBURY
Ethyl Corporation
451 Florida
Baton Rouge, LA 70815

E. L. KNOEDLER
St. Powell Assoc.
501 St. Paul Street
Baltimore, MD 21202

E. G. KOMINEK
Eimco/Envirotech
Salt Lake City, UT 84110

GEORGE R. KOONCE
Minnesota Pollution Control Agency
717 Delaware Street, S.E.
Minneapolis, MN 55414

WILLIAM J. LACY
Environmental Protection Agency
Xerox Building
Washington, DC 20460

RONALD M. LEACH
Michigan Dept. of Agriculture
Lewis Cross Building
Lansing, MI 48913

PAUL F. LEAVITT
Gerber Products Co.
Fremont, MI 49412

SERGE LESSARD
Quebec Water Board
585 East Charest Blvd.
Quebec, P.Q., Canada

ARTHUR W. LILES
ESSO
Murray Hill, NJ 07974

EDMOND P. LOMASNEY
Environmental Protection Agency
1421 Peachtree St., N.E.
Atlanta, GA 30309

WALTER F. LUEHRS
General Foods Corp.
1551 E. Willow Street
Kankakee, IL 60901

DARYL R. LUND
University of Wisconsin
Dept. of Food Science
5 Babcock Hall
Madison, WI 53706

ROGER J. LUTZ
Gerber Products Co.
445 State Street
Fremont, MI 49412

JOHN MACCAGNAN
Beech-Nut, Inc.
460 Park Avenue
New York, NY 10022

STAFFORD J. MACHAS
Quaker Oats Company
Merchandise Mart Place
Chicago, IL 60654

H. MARTIN MAHIN, JR.
ACS Publications
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Washington, DC 20036

JOSEPH MARKIND
Westinghouse
852 Browning Place
Morristown, NJ 07960

DAVID R. MARSHALL
Shilstone Test Laboratories
814 Conti Street
New Orleans, LA 70112

JAMES C. MARTIN
U. S. Army Corps of Engineers
Fort of Pyrtania
New Orleans, LA 70133

TIM A. MATZKE
Environmental Protection Agency
1600 Patterson
Dallas, TX 75201

A. FRANK MAULDIN
Domingue, Szabo & Assoc.
117 Calco Boulevard
Lafayette, LA 70501

WILLIAM H. McCOMBS
McCombs, Knutson Assoc.
12805 Olson Highway
Minneapolis, MN 55441

JOHN W. McNEIL
Autotrol Corporation
5855 N. Glen Pk. Road
Milwaukee, WI 53092

ANTHONY V. METZNER
Carborundum
Box 1269
Knoxville, TN 37901

SAMUEL P. MEYERS
Dept. of Food Science
Louisiana State University
Baton Rouge, LA 70803

GAUVIN MICHEL
Quebeck Water Board
585 East Charest Boulevard
Quebec, P.Q., Canada

JOHN A. MIKES
Lundy Electronics
71 Grace Avenue
Great Neck, NY 11021

VERLIS E. MILLER
National Fruit Prod. Co., Inc.
P. O. Box 609
Winchester, VA 22601

PAUL MINOR
Environmental Protection Agency
Washington, DC 20460

THOMAS E. MOLE
Quaker Oats, Inc.
Merchandise Mart Pl.
Chicago, IL 60654

ARTHUR E. MOLIN
Environmental Protection Agency
100 California Street
San Francisco, CA 94111

WILLIAM A. MONGE
Libby, McNeill & Libby
5555 West 115th Street
Worth, IL 60482

A. J. MONTA
Welch Foods, Inc.
#2 South Partage Street
Westfield, NY 14787

PATRICK MOONEY
Louisiana State University
40 Killdeer Street
New Orleans, LA 70124

P. H. MULCAHY
Envirotech Corporation
P. O. Box 300
Salt Lake City, UT 84110

LEE A. MULKEY
Environmental Protection Agency
Southeast Water Laboratory
College Station Road
Athens, GA 30601

JAMES H. OATES
J. R. Simplot Co.
Box 1059
Caldwell, ID 83605

L. DONALD OCHS
E. I. DuPont
Experimental Station
Wilmington, DE 19898

WILLIAM A. PARSONS
Arthur G. McKee
6200 Oak Tree Boulevard
Cleveland, OH 44131

JAMES R. PATRICK, Jr.
Environmental Protection Agency
1421 Peachtree Street, NE
Atlanta, GA 30309

WAYNE L. PAULSON
University of Iowa
4110 Engineering Building
Iowa City, IA 52240

J. DONALD PAULUS
Whitman Requardt & Assoc.
#2 West Preston Street
Baltimore, MD 21201

EDGAR H. PAVIA
Pavia-Byrne Engineering Corp.
431 Gravier Street
New Orleans, LA 70130

GRANVILLE PERKINS
Artichoke Industires, Inc.
11599 Walsh Street
Castroville, CA 95012

PALMER L. PETERSON
National Marine Fisheries Service
2725 Montlake Boulevard, East
Seattle, WA 98102

JIM T. PETROSKY
Vulcan Materials Co.
P. O. Box 545
Wichita, KS 67201

RALPH W. PIKE
Louisiana State University
6053 Hibiscus Drive
Baton Rouge, LA 70803

SHELDON B. POLLACK
Amstar Corporation
266 Kent Avenue
Brooklyn, NY 11211

LAWRENCE M. POTTER
VPI & SU
Blacksburg, VA 24061

DAVID M. POXTON
Michigan Dept. of Commerce
Lansing, MI 48901

CARLOS QUIROGA
Pavia-Byrne Eng. Corp.
431 Gravier Street
New Orleans, LA 70130

JACK W. RALLS
National Canners Association
1950 Sixth Street
Berkeley, CA 94710

DUANE H. RASMUSSEN
Jacobs Engineering Company
837 South Fair Oaks Avenue
Pasadena, CA 91105

A. P. REDOVNIKOVICH
U. S. Army Corps of Engineers
805 Oaklawn Drive
Metairie, LA 70005

AUSTIN RHOADS
American Frozen Foods Institute
919 - 18th Street, NW
Washington, DC 20006

JOE G. RICHARD, JR.
Ethyl Corporation
451 Florida Street
Baton Rouge, LA 70801

ALLYN RICHARDSON
Environmental Protection Agency
2303 J. F. Kennedy Building
Boston, MA 02203

H. S. RITTER
PPG Industries, Chemical Div.
Columbia Center
Barberton, OH 44203

CHRIS D. ROBERTS
Contadina Foods, Inc.
P. O. Box 29
Woodland, CA 95695

CHARLES S. ROGERS
Environmental Protection Agency
Solid Waste Research Division
5555 Ridge Avenue
Cincinnati, OH 45213

WALTER W. ROSE
National Canners Association
1950 Sixth Street
Berkeley, CA 94710

LARS ROSENGREN
Swedish Embassy
Washington, DC 20037

JAMES D. ROUSSEL
Amstar Corporation
7417 North Peters Street
Arabi, LA 70032

EUGENE E. ROZACKY
Environmental Protection Agency
Permits Section
1600 Patterson Street
Dallas, TX 75201

PAUL H. RUSSELL, JR.
Harnish & Lookup Associates
615 Mason Street
Newark, NY 14513

JAMES A. SANTROCH
Environmental Protection Agency
100 California Street
San Francisco, CA 94111

THOMAS N. SARGENT
Environmental Protection Agency
Southeast Water Laboratory
College Station Road
Athens, GA 30601

KENNETH H. SAULS
Amstar Corporation
1253 Avenue of Americas
New York, NY 10020

LOUIS SAVARESE
Beech-Nut, Inc.
Canajoharie, NY 13317

W. J. SAVOY
Cities Service Oil Co.
2100 Orchid
Lake Charles, LA 70601

JOHN B. SCHENK
Environmental Control Technology
3983 Research Park Drive
Ann Arbor, MI 48104

CURTIS J. SCHMIDT
SCS Engineers
4014 Long Beach Boulevard
Long Beach, CA 90807

RONALD C. SCHMIDT
Ionics, Inc.
P. O. Box 99
Bridgeville, PA 15017

CHARLES E. SCHOLLMEIER
A. E. Staley Mfg. Co.
Route 7, Majors Lane
Decatur, IL 62521

G. H. SCHWARTZ, Jr.
Sverdrup & Parcel
800 North 12th Street
St. Louis, MO 63101

J. M. SHACKELFORD
Environmental Protection Agency
Washington, DC 20460

A. L. SHEWFELT
Georgia Experimental Station
Experiment, GA 30212

KIM SHIKAZE
Dept. of Environment
Ottawa, Canada KIV-8N2

HOWARD H. SHOCKEY
National Fruit Products Company
P. O. Box 609
Winchester, VA 22601

CHARLES D. SIEBENTHAL
Metcalf & Eddy
1029 Corporation Way
Palo Alto, CA 94303

ADEN R. SIRLES
Komine, Sanderson Engineering Corp.
11 West Oxmoor Road
Birmingham, AL 35209

CHARLES SMALLWOOD, JR.
North Carolina State University
Mann Hall
Raleigh, NC 27607

GERALD T. SMITH
Environmental Protection Agency
2390 Palmour Drive, NE #11
Atlanta, GA 30305

A. L. STAFFORD
Virginia Dept. of Agriculture
1444 East Main Street
Richmond, VA 23219

LEONARD J. STAR
Fredonia Products Co.
Fredonia, NY 14063

MATTHEW M. STAWIARSKI
Central Soya Co., Inc.
1825 North Laramie
Chicago, IL 60639

RICHARD W. STERNBERG
National Canners Association
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HERBERT E. STONE
Del Monte Corporation
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San Francisco, CA 94022

LEALE STREEBIN
University of Oklahoma
School of Civil Engineering
202 H. Boyd
Norman, OK 73069

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RICHARD A. WIDSETH
Webster Foster & Weston
216 South Main Street
Crookston, MN 56716

FREDERICK WILLIAMS
Ontario Research Foundation
Sheridan Park
Mississauga, Ontario, Canada

JACK L. WITHEROW
Environmental Protection Agency
P. O. Box 1198
Ada, OK 74820

BOBBY J. WOOD
National Marine Fisheries Service
P. O. Drawer 1207
Pascagoula, MS 39567

S. C. YIN
Environmental Protection Agency
Robert S. Kerr Water Res. Ctr.
P. O. Box 1198
Ada, OK 74820

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